Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 260 AUGUST, 1955 No. 2

INCREASING INVENTIVE CREATIVENESS

BY

C. D. TUSKA[1]

Inventiveness per capita per year in the United States, measured by patent applications, shows a peak after World War I and thereafter a decline of about 40 per cent. The inventive rate, on a similar scale, in Great Britain is only down one-sixth from the 1928 peak. Furthermore, the per capita patent applications in Great Britain now exceed the United States. Germany's per capita patent applications in the early 1940's were down about 50 per cent from their 1930 peak which exceeded United States and Great Britain.[2] I do not have the latest figures for Germany. While I do not know what effect the division of Germany may have, I expect that the recovery noted in other fields also applies to invention at least in Western Germany (see Fig. 1).

A Bill (H.R. 4267) recently introduced in the Congress by Representative Hosmer proposes that a Commission be established to investigate and study our patent laws. The Commission is to determine "what changes . . . are necessary . . . to promote a greater contribution to continued technological advancement by the United States, with particular regard to the problem of how to stimulate an increased contribution on the part of the individual inventor." Let us hope that the proposed Commission does not conclude that an increasing *number* of U. S. Patent Applications means that we do not have a falling rate per capita. In these times of international stress, I believe, we should be concerned with relative international rates, and especially with our own declining rate.

[1] Director of Patent Operations, RCA Laboratories, Radio Corporation of America, Princeton, N. J.

[2] These figures do not exactly indicate the national invention per capita rate for the United States, Great Britain or Germany, because in each case foreign origin patent applications are included.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

Now that I have pointed out that quantity of inventiveness appears to be falling, I do not plan to use much space looking for explanations. Neither do I propose to blame the Republicans or the Democrats because most of us are one or the other or neutral so in the final analysis it is our own fault. Rather than complain I want to illuminate a few spots. Some of the crannies may be obvious, some may be obscure, some may be forgotten, but there is always the chance that my shots in the dark will start you on a path to invention. Only one thing do I promise: I shall not make your inventions for you.

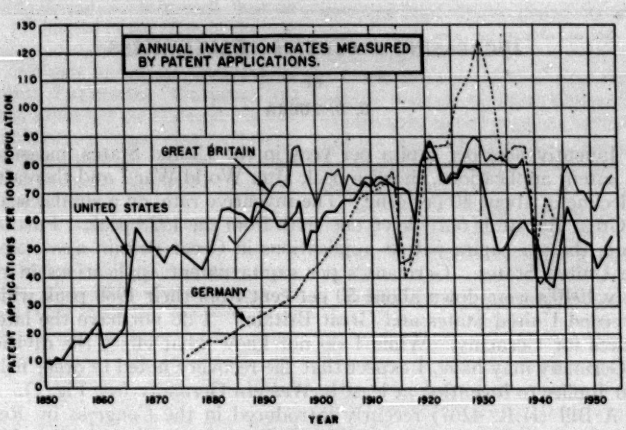

FIG. 1.

ADVERSITY

Most of us have heard or read "necessity is the mother of invention." According to my theory adversity helps too. If my theory is correct, the curve for Germany should take, or probably already has taken, an upward trend. Anyway, apply the adversity theory and you'll find that not a few inventions were begat under that kind of stress. If you demand examples, study Morse's invention of the telegraph, Bell's telephone, Goodyear's vulcanization of rubber, Holland's submarine, and there are surely many more. Please do not think I advocate poverty, ill health, or any other misfortune just to advance invention. You may have adversity in the form of apparently insoluble problems at home. Direct your mind toward invention. Not only will mental concentration in another field lighten your burdens, but you may make a discovery or invention of great merit.

SERENDIPITY

That tinkling word was coined by Walpole. It means the gift of finding valuable or agreeable things *not sought for*. Serendipity is certainly a happy state of being when it leads to invention. In seeking a super high frequency amplifier do not let surprise brush away a discovery of a very stable and powerful super high frequency oscillator. True, you were not looking for the latter, but be sagacious enough to examine what you found. There was plenty of serendipity in Thomas Edison for I believe that it was that state which brought him to the phonograph. Don't overlook what you were not seeking!

CURIOSITY

The word "curiosity" has a connotation implying meddlesomeness. "Curiosity" herein has the sense of "careful attention" and "disposition to inquire." Newton's formulation of the laws of gravity may have been started by curiosity. Don't you suppose that curiosity was the important factor first in Zacharias Janseen's and later in Anton Leeuwenhoek's inventions of the microscope? Perhaps it was an ingredient in the invention of the stethoscope. If you would invent, be curious! When you observe the unusual, ask yourself "why?," not "so what?" Furthermore, you may not observe, unless you pay careful attention. Nature has a way of sometimes hiding her secrets; pry into them. Cultivate scientific curiosity!

NONIMITATIVENESS

If you would invent, be nonimitative. The important discoveries and inventions are more apt to occur when exploring a new path. Be sure to keep your mental scouts alert. Do not travel an unchartered path so fast that the scouts can not, *on proper occasion*, mentally trod an attractive byroad. Even a "dead-end" street could have a treasure at the end; then perchance it may not be a dead end. T. Brown seemed to express the point when he wrote: "Not picked from the leaves of any author, but bred amongst the weeds and tares of mine own brain." Avoid imitation—it stifles invention!

SYNTHESIS

In a recent article[3] "Here's How to Train Your Own Inventors," Richard Gehman identifies two approaches to solve a problem—analysis and synthesis. He then defines synthesis as "a solution that is based on hunch or intuition." Gehman's article states that the analytical approach "examining each aspect step-by-step" rarely leads to creation. Felix Morley, in the same publication, while discussing the problems of personnel and public relations writes ". . . and where solutions will

[3] *Nations Business*, February 1955, pp. 28–30 and 100,

not come out of test tubes, or off drawing boards, mere technical efficiency sometimes seems more of a handicap than an asset."

It may be true that asymmetrical scientific training may discourage invention. One who foresees only all of the difficult technical difficulties can too easily conclude that the problem at hand has no practical solution. However, many with all the essential scientific facts tucked away in their minds can, sometimes without conscious effect, emerge with an almost complete solution of a baffling problem. You can call it synthesis, intuition or hunch. Distinguish it from analytic, if you wish, but do not overlook the mental process of "forgetting the problem for awhile." If you do, you may suddenly be surprised by having a workable, ready-made invention pop out of your "unknown" mental excursions. In urging that you be mindful of the "subconscious" approach to invention, please do not get the notion that I am against excogitation, for I am not.

RECOGNITION OF THE PROBLEM OR THE NEED

Dr. John M. Miller, who was awarded the Institute of Radio Engineers Medal of Honor in 1953, once told me that recognition of the problem was not infrequently the royal road to invention. If the problem is stated very clearly, the solution may come almost automatically. Recognizing an unsatisfied public need for a particular device, can often inspire one to make the required invention. When we have the clearly stated problem or have visions of the desirable but unavailable article, the mental approach may be analytic or synthetic. Apparently the patent conscious inventor need not be too concerned as to the manner[4] in which he made the invention. Anyway, see whether you can't recognize some problems or needs, and then persistently seek the solution.

THE HAPPY ACCIDENT

When Robert Burns wrote: "The best laid schemes o' mice an' men gang aft a-gley," he did not have in mind a "happy accident." But I say to you, when your experiments "gang aft a-gley," most carefully examine the unexpected, and even the undesired. Therein you may find "a happy accident" or a great invention. Serendipity, curiosity, and sagacity should join hands if you are to discover something important in the failures to reach the original target of your quest.

Recently Dr. Harry Olson, a neat inventor if you ask me, recited that he was hard at work on his ribbon or velocity microphone.[5] He did not understand why the rear response was practically non-existing.

[4] ". . . Patentability shall not be negatived by the manner in which the invention was made." 35 USC 103.

[5] Olson, U. S. Patent 1,885,001, "Apparatus for Converting Sound Vibrations into Electrical Variations."

He had expected non-directional response pattern. Searching for the cause he found that the mechanic in building the model had failed to cover a hole. A finger over the hole clearly demonstrated the error.

Many might have remedied the mistake and moved on to the desired result. Dr. Olson not only found the cause but recognized the invention or discovery of an improved microphone[6] in which the response pattern could be readily changed. It takes a sagacious inventor to recognize and to profit by the happy accidents.

Charles Goodyear said it this way: "I was encouraged in my efforts by the reflection that what is hidden and unknown and cannot be discovered by scientific research, will most likely be discovered by accident, if at all, by the man who applies himself most perseveringly to the subject and is most observing of everything related thereto."

Perhaps you would like another example of the "accidental" invention. My good friend P. H. Spencer, the inventor son of a Yankee inventor of great note, suddenly realized that tomorrow was his child's birthday. He had forgotten to buy a present. The stores were closed. He hastened to his shop and equally hastily conceived and hurriedly built a rubber-band powered toy ornithopter. The device was presented and the unexpected happened: it actually flew and attained an altitude higher than its launching point. Spencer then decided that he had something. He reasoned that if he carefully constructed a second model, it would perform better. The second model was made with all the precision he could command. The well constructed model failed to fly!

After recovering from the surprise Spencer started to reason, and to compare the precise model with the earlier model. He discovered that the first model had included, albeit unintentionally, misaligned pivots or bearings for the main wing spars. The misalignment cause the wing to sweep to the rear on the up stroke and forward on the down stroke. This wing motion, quite by accident, produced "lift." In the precise model the wings simply rose and fell but did not lift. Spencer had made a discovery—a patentable invention.[7]

IMAGINATION

Thus seven circumstances of invention have been characterized. Doubtless there are many others. Also mere circumstances are not sufficient to foster invention. Invention requires something more. Some mental act must be applied. The invention must be "conceived." Let us avoid problems of psychology and semantics by calling the mental act "imagination." You may protest that you don't possess imagination. Most children have it to a high degree. You may not have

[6] Olson, U. S. Patent 2,301,638, "Sound Translating Apparatus."

[7] Spencer, U. S. Patent 1,907,887, "Toy Aircraft."

cultivated it but you certainly have not lost it. Emerson wrote: "Imagination is not a talent of some men but is the health of every man."

I could write at length on constructive imagination, creative imagination, productive imagination, and many other forms of visionary thinking. Fortunately, that is not necessary because I can refer to "Applied Imagination—Principles and Procedures of Creative Thinking" by Alex F. Osborn. Read this recent book or one of Mr. Osborn's earlier works if you would awake or stimulate your imagination.

CREATIVE IMAGINATION × PROPER EFFORT = SUCCESS

Favorable circumstances, and an abundance of creative imagination will surely help invention. I will even throw in luck, but I am sure I have not named the essential ingredient. Unfortunately, I do not know the word for it. A recent newspaper article stated that Dr. Harrison G. Gough, a research psychologist at the University of California, discovered a way to test for "it." He tackled the problem—"why some gifted persons make a place for themselves in the world and why others with equal gifts wander aimlessly and let their gifts go to waste." Dr. Gough provided the name "psychological persistence." However, I shall call the essential ingredient "effort."

Frequently the difference between a success and failure in invention is "effort." Surely few inventions are born without effort. You may go through all the mental steps, but do no more, and your invention will die aborning. An invention, if it is to have the slightest patentable significance, must be disclosed to others. That takes effort. The disclosure should be in writing. That too takes effort. Constructive reduction to practice, that is, filing a patent application, takes more effort. Actual reduction to practice takes still more effort.

Perhaps a summary in algebraic equation form might be helpful:

(*Surround yourself with favorable circumstances*) + (*Exercise creative imagination*) × (*Apply effort . . .* + *apply effort*^{n}) + (k, where k = good luck) = One approach to invention.

DETERMINATION OF APERTURE PHASE ERRORS IN MICROWAVE REFLECTORS *

BY

DAVID K. CHENG [1] AND PRANAS GRUSAUSKAS [1]

ABSTRACT

Using the vector notation of differential geometry, a general expression is obtained for the phase error in an aperture plane of any given reflector when the equation of the incident wavefront is known. This phase error is important because it has a direct bearing on the radiation pattern of a microwave antenna system. Examples are given to illustrate the application of the general formula. For the special case of a point source, the formula can be readily applied to determine the aperture phase distribution for any source location.

INTRODUCTION

By means of a vector notation for surfaces, Kelleher[2] has derived a set of relations among an incident wavefront, a reflector and a reflected wavefront so that given any two, the third can be found. In microwave antenna work, the phase distribution in an aperture plane, rather than the reflected wavefront, is of importance because it is the former that has a direct bearing on the radiation pattern of a microwave antenna system. Phase errors in an aperture plane are not simply related to deviations of the reflected wavefront from the aperture plane; they correspond to each other only when the congruence of reflected rays is everywhere parallel to the reflector axis which is a rare and special case.

The present paper derives a general expression for the phase error in an aperture plane of any given reflector when the equation of the incident wavefront is known. One special feature of this expression is that it circumvents the necessity of first determining the equation of the reflected wavefront which is itself usually a rather complicated expression.

In the important case of a paraboloidal reflector with a point source, the vector representing the incident wavefront would be a constant and the general expression can be applied readily to determine the aperture phase errors resulting from either on-axis or off-axis defocusing. Illustrative examples are given.

THE GENERAL EXPRESSION FOR APERTURE PHASE ERROR

Refer to Fig. 1, let vectors $\mathbf{R}(s,t)$ and $\mathbf{A}(u,v)$ represent a reflector surface and an incident wavefront, respectively.

* The work described in this paper was supported in part by the Rome Air Development Center, USAF, under Contract No. AF 30(602)–1360.

[1] Electrical Engineering Department, Syracuse University, Syracuse, N. Y.

[2] K. S. KELLEHER, "Relations Concerning Wave Fronts and Reflectors," *J. Appl. Physics*, Vol. 21, p. 573 (1950).

$$\mathbf{R}(s,t) = R_1(s,t)\mathbf{i} + R_2(s,t)\mathbf{j} + R_3(s,t)\mathbf{k} \tag{1}$$

$$\mathbf{A}(u,v) = A_1(u,v)\mathbf{i} + A_2(u,v)\mathbf{j} + A_3(u,v)\mathbf{k} \tag{2}$$

(s,t) and (u,v) are two sets of arbitrary parameters; either set can be expressed in terms of the other through the following relationship:

$$\begin{aligned}(\mathbf{R} - \mathbf{A})\cdot\mathbf{A}_u &= 0\\ (\mathbf{R} - \mathbf{A})\cdot\mathbf{A}_v &= 0,\end{aligned} \tag{3}$$

where the subscripts denote partial differentiations. Equations 3 state essentially the condition that the incident rays are normal to the incident wavefront. It is noted that if $\mathbf{A}$ is a constant (point source), only parameters s and t exist and there is no need for Eqs. 3.

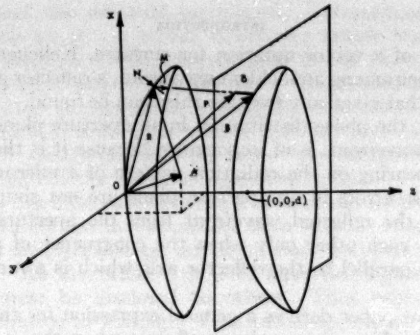

FIG. 1. Vector notation of reflector and wavefronts.

$\mathbf{B}$ is a vector representing the reflected wavefront. For a given optical path-length C, the expression for $\mathbf{B}$ can be determined.[2] Let $\mathbf{P}$ be an aperture plane parallel to the xy-plane and located at a distance d from it.

$$\mathbf{P}\cdot\mathbf{k} = d. \tag{4}$$

Then it can be shown that[3]

$$\mathbf{P}(u,v,s,t) = \mathbf{R} + \frac{(d - \mathbf{R}\cdot\mathbf{k})\{(\mathbf{R} - \mathbf{A}) - 2\mathbf{n}[\mathbf{n}\cdot(\mathbf{R} - \mathbf{A})]\}}{(\mathbf{R} - \mathbf{A})\cdot\mathbf{k} - 2(\mathbf{n}\cdot\mathbf{k})[\mathbf{n}\cdot(\mathbf{R} - \mathbf{A})]}, \tag{5}$$

where $\mathbf{n}$ is a unit normal to the reflector surface.

The difference in path-length, δ, is the deviation of the reflected wavefront $\mathbf{B}$ from the aperture plane $\mathbf{P}$ along the reflected ray (in the direction of $\mathbf{m}$). This is equal to

$$\delta = C - [|\mathbf{R} - \mathbf{A}| + |\mathbf{P} - \mathbf{R}|]. \tag{6}$$

[3] See Appendix.

From Eqs. 5 and 6, one obtains after some simplification

$$\delta = C - |\mathbf{R}-\mathbf{A}| \frac{d - \{\mathbf{A}\cdot\mathbf{k} + 2(\mathbf{n}\cdot\mathbf{k})[\mathbf{n}\cdot(\mathbf{R}-\mathbf{A})]\}}{(\mathbf{R}-\mathbf{A})\cdot\mathbf{k} - 2(\mathbf{n}\cdot\mathbf{k})[\mathbf{n}\cdot(\mathbf{R}-\mathbf{A})]}. \tag{7}$$

Equation 7 gives the general expression for the difference in path-length with reference to a plane **P** parallel to the xy-plane for any given reflector **R** with an arbitrary incident wavefront **A**. The corresponding phase error in the aperture plane is $(2\pi/\lambda)\delta$. There is no need to determine the equation of the reflected wavefront first.

For the special case of a point source situated on the axis of a symmetrical reflector, the optical path-length C and the distance d are related simply by the following equation:

$$C = |\mathbf{A}| + d \tag{8}$$

and the aperture plane **P** is tangent ($\delta = 0$) to the reflected wavefront **B** at $z = d$.

PARABOLOIDAL REFLECTOR WITH DEFOCUSED PRIMARY SOURCE

A perfect paraboloidal reflector with a point source at its focus would give plane reflected wavefronts. In other words, if in Eq. 8, one has

$$C = f + d \tag{9}$$

f being the focal length of the paraboloidal reflector, then Eq. 7 would be reduced to $\delta = 0$. However, in practical usage, the primary source may be off-focus both intentionally and unintentionally. Intentional defocus is a method[4] used in practice to simulate far-zone (Fraunhofer region) radiation patterns of antennas of large aperture in the quasi-near zone (optical-Fresnel region). Unintentional defocus may be the result of the indefiniteness of the phase center of the primary horn feed and the inaccurate positioning of the feed. In both cases, it is necessary to determine the phase distribution in an aperture plane before the effect of the off-focus arrangement on the radiation characteristics of the system can be analyzed.

A paraboloidal surface with focal length f can be written in Cartesian coordinates as

$$\mathbf{R}(x,y) = x\mathbf{i} + y\mathbf{j} + \frac{x^2 + y^2}{4f}\mathbf{k}. \tag{10}$$

From differential geometry, the unit normal **n** to **R** is

$$\mathbf{n} = \frac{\mathbf{R}_x \times \mathbf{R}_y}{|\mathbf{R}_x \times \mathbf{R}_y|} = \frac{1}{\sqrt{x^2 + y^2 + 4f^2}}(-x\mathbf{i} - y\mathbf{j} + 2f\mathbf{k}). \tag{11}$$

[4] D. K. CHENG AND S. T. MOSELEY, "On-Axis Defocus Characteristics of the Paraboloidal Reflector," paper presented at IRE Western Convention in Los Angeles, Calif., August 25, 1954.

Let the location of the point source be represented by

$$\mathbf{A} = A_1\mathbf{i} + A_2\mathbf{j} + A_3\mathbf{k}, \tag{12}$$

where A_1, A_2 and A_3 are constants. Then, using Eq. 7, one obtains the deviation in path-length

$$\delta = C - \sqrt{(x-A_1)^2+(y-A_2)^2+\left(\frac{x^2+y^2}{4f}-A_3\right)^2} \times \frac{(d-A_3)(x^2+y^2+4f^2)-2f[2A_1x+2A_2y-4A_3f-(x^2+y^2)]}{\frac{1}{4f}(x^2+y^2-4fA_3)(x^2+y^2+4f^2)-2f[2A_1x+2A_2y-4A_3f-(x^2+y^2)]}. \tag{13}$$

For the special case of $A_1 = A_2 = 0$, $A_3 = f + \epsilon$, and $C = 2(f + \epsilon)$, ϵ being the amount of defocus, Eq. 13 reduces to

$$\delta' = 2\left\{1+\epsilon'-\frac{[r'^2+4(1+\epsilon')]^2\cdot\sqrt{1-16r'^2\epsilon'/[r'^2+4(1+\epsilon')]^2}}{[r'^2+4(1+\epsilon')]^2-4\epsilon'[r'^2+4(1+\epsilon')]-8\epsilon'r'^2}\right\}, \tag{14}$$

where

$$\epsilon' = \epsilon/f$$
$$r'^2 = (x^2+y^2)/f^2 \tag{15}$$

and

$$\delta' = \delta/f.$$

That $\delta' = 0$ when $\epsilon' = 0$ (primary feed at focus) is readily seen from Eq. 14. Curves of δ' versus r' are plotted in Fig. 2 for three values of defocus distance normalized with respect to focal length, $\epsilon' = 0.05$, 0.1 and 0.2. Positive values of δ' represent phase advance. These are the results of displacing the primary feed away from the focus in the positive z-direction.

SPHERICAL REFLECTOR

The case of a spherical reflector with a point source is considered here as a second example; the difference between path-length deviation and geometrical deviation of a reflected wavefront from an aperture plane will be very clear in this case.

The vector equation for a spherical reflector of radius a with center at $z = a$ is

$$\mathbf{R}(x,y) = x\mathbf{i} + y\mathbf{j} + (a - \sqrt{a^2 - r^2})\mathbf{k}. \tag{16}$$

The unit normal to $\mathbf{R}$ is

$$\mathbf{n} = -\frac{1}{a}(x\mathbf{i} + y\mathbf{j} - \sqrt{a^2 - r^2}\,\mathbf{k}). \tag{17}$$

Assume that the point source is located at $z = \alpha$, then

$$\mathbf{A} = \alpha\mathbf{k}. \tag{18}$$

Letting $\mathbf{P}\cdot\mathbf{k} = \alpha$ and substituting Eqs. 16, 17 and 18 in Eq. 7, one has

$$\delta = 2\left[\alpha - \sqrt{\alpha^2 + 2a(a-\alpha)(1-\sqrt{1-r^2/a^2})}\right.$$
$$\left.\times \frac{(a-\alpha)(1-r^2/a^2) - a\sqrt{1-r^2/a^2}}{(a-\alpha)(1-2r^2/a^2) - a\sqrt{1-r^2/a^2}}\right]. \tag{19}$$

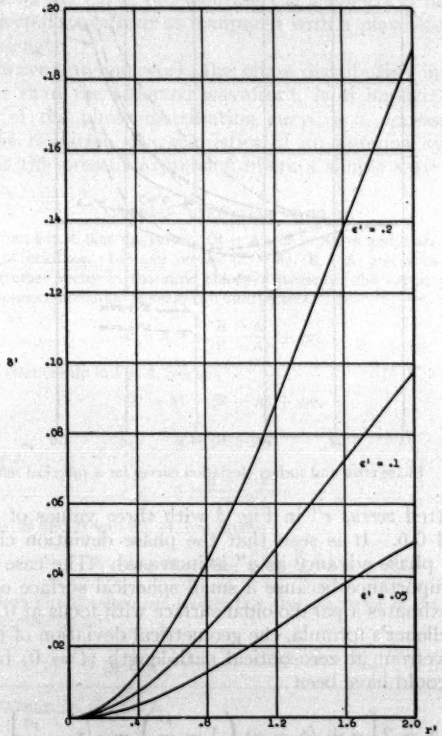

FIG. 2. Phase-error curves for a paraboloidal reflector.

Normalizing Eq. 19 with respect to radius a, Eq. 19 becomes

$$\delta'' = 2\left[\alpha'' - \sqrt{\alpha''^2 + 2(1-\alpha'')(1-\sqrt{1-r''^2})}\right.$$
$$\left. \times \frac{(1-\alpha'')(1-r''^2) - \sqrt{1-r''^2}}{(1-\alpha'')(1-2r''^2) - \sqrt{1-r''^2}}\right], \quad (20)$$

where

$$\alpha'' = \alpha/a, \quad r'' = r/a, \quad \text{and} \quad \delta'' = \delta/a. \quad (21)$$

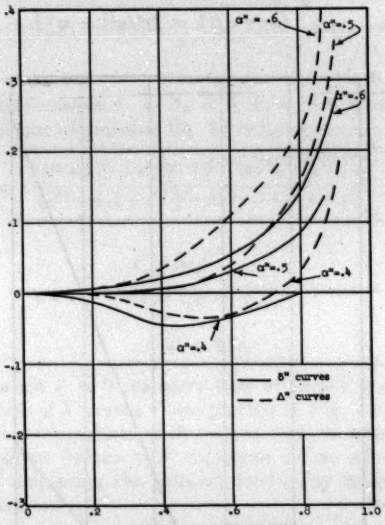

FIG. 3. Phase-error and surface-deviation curves for a spherical reflector.

δ'' is plotted *versus* r'' in Fig. 3 with three values of α'', namely, 0.4, 0.5, and 0.6. It is seen that the phase deviation changes from phase lag to phase advance as α'' is increased. The case of $\alpha = 0.5a$ is of some importance because a small spherical surface of very large radius approximates a paraboloidal surface with focus at $0.5a$.

Using Kelleher's formula, the geometrical deviation of the fictitious reflected wavefront at zero optical path-length ($C = 0$) from a plane at $z = -\alpha$ would have been

$$\Delta = 2\left[\alpha + (a-\alpha)\left(1 - \frac{r^2}{a^2}\right) - \sqrt{1 - \frac{r^2}{a^2}}\right] \quad (22)$$

which, after normalization, becomes

$$\Delta'' = 2[\alpha'' + (1 - \alpha'')(1 - r''^2) - \sqrt{1 - r''^2}]. \tag{23}$$

Curves of Δ'' *versus* r'' are also plotted in Fig. 3 for the same values of α'' for comparison. It is seen that the Δ'' curves are quite different from the δ'' curves.

CONCLUSION

A general expression has been derived for determining the phase error in an aperture plane of any given reflector when the equation of the incident wavefront is known. It is not necessary to obtain the equation of the reflected wavefront first. The phase-error curve is not the same as the curve representing the geometrical deviation of a fictitious reflected wavefront as compared with a plane located at zero optical path-length.

In microwave antenna work, the phase distribution in an aperture plane, rather than the reflected wavefront, is of importance; the determination of the phase distribution curve is a necessary step for analyzing the radiation characteristics of an antenna system. It is believed that the present expression offers a simple way of obtaining such a curve.

APPENDIX—DERIVATION OF EQ. 5

It is clear from Fig. 1 that the vectors $(\mathbf{R} - \mathbf{A})$, $(\mathbf{P} - \mathbf{A})$, $\mathbf{m}$ and $\mathbf{n}$ are coplanar and all lie in the plane of incidence. Let unit vectors $(\mathbf{R} - \mathbf{A})/|\mathbf{R} - \mathbf{A}|$ and $\mathbf{m}$ be the basis of this plane, then any other vector in the same plane, in particular the vector $(\mathbf{P} - \mathbf{A})$, can be expressed as a linear combination of these two unit vectors.

$$\mathbf{P} - \mathbf{A} = \alpha \frac{\mathbf{R} - \mathbf{A}}{|\mathbf{R} - \mathbf{A}|} + \beta \mathbf{m}. \tag{24}$$

From a triangle relationship in Fig. 1, one has

$$(\mathbf{P} - \mathbf{A}) = (\mathbf{R} - \mathbf{A}) + \beta \mathbf{m}. \tag{25}$$

Therefore

$$\alpha = |\mathbf{R} - \mathbf{A}| \tag{26}$$

and since $\mathbf{P} \cdot \mathbf{k} = d$,

$$\beta = \frac{d - \mathbf{R} \cdot \mathbf{k}}{\mathbf{m} \cdot \mathbf{k}}. \tag{27}$$

Substituting Eqs. 26 and 27 into Eq. 24, one obtains

$$\mathbf{P} - \mathbf{A} = (\mathbf{R} - \mathbf{A}) + \left(\frac{d - \mathbf{R} \cdot \mathbf{k}}{\mathbf{m} \cdot \mathbf{k}}\right) \mathbf{m}. \tag{28}$$

Equation 5 follows directly when one realizes that the unit vector in the direction of the reflected ray is expressible as[5]

$$\mathbf{m} = \frac{1}{|\mathbf{R} - \mathbf{A}|} [(\mathbf{R} - \mathbf{A}) - 2\mathbf{n}[\mathbf{n} \cdot (\mathbf{R} - \mathbf{A})]]. \tag{29}$$

[5] K. S. KELLEHER, *op. cit.*, Eq. 2.

Improved Transistors. — Transistors recently developed at the General Electric Research Laboratory, Schenectady, N. Y., can be used in television, radar, shortwave radio, and other electronic devices where high-frequency requirements have previously required bulkier vacuum tubes. The new transistors were made possible by the development of a revolutionary new method of producing the crystal "hearts" of transistors.

Dr. C. G. Suits, who is a GE vice president and director of research, said, "Transistors made by the new 'melt-back' process can operate efficiently at frequencies five times higher than ordinary transistors, and at these high frequencies the new transistors show greatly improved power-amplification characteristics."

Developer of the "meltback" principle is Dr. Robert N. Hall, young GE scientist who also developed the well-known "rate-growing" process for making junction transistors.

"Meltback" significantly improves the control of impurities in the thin layers of germanium or silicon crystals from which transistors are made. These crystals are smaller than a grain of wheat, and some layers must be as thin as 1/5000th of an inch for satisfactory performance at high frequencies.

In previous processes, crystals were formed from a pool of molten metal, and the layers created by cycling the rate of growth. Scientists have been faced with the problem of keeping materials in different layers from contaminating each other during the 20 minutes it takes the molten mass to solidify and cool to room temperature. This has meant thicker separating layers than are desirable for high-frequency use. In Hall's new process, the cooling time is greatly shortened, there is less inter-mixing between layers, and the layers therefore can be thinner. Thin layers allow electrons to travel more quickly from one side of the crystal to the other, thus increasing the frequency at which the transistor can operate.

Commercial methods previously available for making transistors involved the production of cigar-sized crystals of germanium or silicon and cutting them into thousands of tiny pieces. Hall's new method uses thin, wire-like crystals, and because of the reduced cross-section the "melting back" is accomplished quickly and cooling takes place not in 20 minutes but in less than a second. In this short time the number of impurities migrating from their proper layers into adjoining layers is reduced to about 1/30th the former figure. The entire cycle of melting, cooling, and removal of the finished pellet takes only a fraction of a minute.

With this greatly improved control over the movement of impurities, the manufacturer of crystals can successfully produce layers thin enough to meet the requirements of high-frequency operation.

Before development of this process, even the best commercially-available transistors were not useful for many applications above the standard radio frequencies. Now the transistor's advantages of small size and lower power requirements will be available for many additional applications, Dr. Suits pointed out.

"Meltback" transistors also have greatly improved "gain" characteristics. Amplification of current with ordinary transistors usually is approximately 50 times. With the new technique, current gains of several hundred are typical, and results in the thousands have been achieved.

CERTAIN ASPECTS OF THE PROBLEM OF EFFICIENT STRUCTURAL DESIGN

BY

B. KLEIN [1]

SUMMARY

Efficient structural design can be considered to consist of several phases, and various methods exist for the solution of these phases. It is shown how the use of Lagrangian multipliers in conjunction with the calculus of variations leads to the solution of a certain class of problems in efficient structural design involving constraining conditions almost always present in practice. A particular problem is worked to illustrate the method.

INTRODUCTION

The over-all problem of efficient structural design is exceedingly complex both in nature and scope. (In some references the wording "optimum structural design" is used. Since this wording is relative, its usage is avoided here.) Not only must a good design be one of high strength-to-weight ratio and/or high rigidity-to-weight ratio under varying kinds of loadings and operating conditions, but at the same time it must be possible to build, assemble, inspect, and repair the structure with reasonable effort and cost. In reality, the design finally chosen in a specific instance will be a compromise dictated by practical limitations. Theoretically better designs may exist but these possibilities will be ruled out because of practical "constraints."

A. The problem of efficient structural design can be considered to consist of several phases:

1. Investigation of available or potential efficient materials, their properties and potential properties.
2. Investigation of feasible types of construction such as pure monocoque, riveted semi-monocoque, machined, forged or glued integral stiffened, chemically etched structure, sandwich, multi-web, post-stiffened, etc., and combinations of the above.
3. For combinations of 1 and 2, investigation of efficient geometric arrangements of "elements." (Over-all geometry may be specified by other dictates.)
4. For combinations of 1 and 2, investigation of efficient distributions of material, that is, the gages of the "elements."
5. Combinations of 3 and 4.

B. The methods available for the solution of these phases include:

1. Testing—both full scale and model.
2. Theoretical—various mathematical methods and models.

[1] Aerophysics Department, North American Aviation, Inc., Downey, Calif.

3. Analogue methods.
4. Empirical and semi-empirical based on previous data.
5. Rule of thumb based on physical intuition and experience.
6. Combinations of above.

It is not the purpose of the present paper to analyze the phases under *A* nor the aspects of the methods under *B*. The indicated references (1–22)[2] cover some of these items. The purpose of these lists is more to summarize and give a clear picture of what the designer is confronted with and what tools he has available.

It is believed that a certain class of problems in efficient structural design can be solved by a theoretical type approach the basis of which is the calculus of variations in its rigorous sense. The big thing in this method is the use of Lagrangian multipliers to handle the constraining conditions which are present almost always in practice. For example, one may ask: what is the minimum weight design for a given type structure under given loadings so that no fatigue failure or collapse occurs, and so that the maximum deflections are equal to or less than prescribed amounts? These latter conditions are the constraints. Many other kinds of constraints may be specified.

In the present discussion, a particular example is presented to illustrate the power of the use of Lagrangian multipliers in aiding to arrive at a solution of a fairly complicated problem.

LIST OF SYMBOLS

a = span length	W = beam weight
A_{cap} = cap area	W' = weight function
c = beam semi depth	β = parameter
E = Young's modulus	δ = deflection
h = beam depth	δ_0 = deflection function
$k\alpha$ = parameter	δ_{max} = maximum deflection
I = moment of inertia	δ_{sp} = specified deflection
M = bending moment	λ = Lagrangian multiplier
R = reaction	ρ = density
t_{web} = web gage	σ = axial stress
V = shear force	σ_0 = axial stress function
x = coordinate	$\bar{\sigma}$ = axial stress constant
x_0 = location of point of inflection	σ_{sp} = specified axial stress
$\bar{x}$ = location of maximum deflection	τ = shear stress
w = beam loading	τ_{sp} = specified shear stress

I. STATEMENT OF THE PROBLEM

Let it be required to determine a low weight design of a uniformly loaded straight beam on three supports where the length and the depth of the beam are constants, the beam is symmetric about the middle

[2] See the "Bibliography" appended to this paper.

support, and the same material is used throughout the beam *provided:* (*a*) no stress exceeds a certain amount, σ_{sp} or τ_{sp}; and (*b*) no deflection exceeds a certain amount, δ_{sp}. Refer to Fig. 1 for dimensions of the beam and its loading.

II. FORMULATION

Intuition leads one to believe that all axial carrying material should be concentrated in the flanges and all shear carrying material in the web. Furthermore, the neutral plane should coincide with the geometric centerplane of the beam. Therefore one may write:

1. Total weight of the beam:

$$W = W_{cap} + W_{web} = 2\int_0^a 2A_{cap}dx + 2\int_0^a t_{web}hdx. \tag{1}$$

Because of symmetry, only one half of the beam shall be considered henceforth.

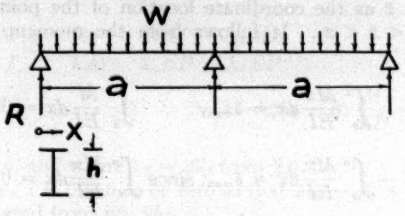

FIG. 1. Two span beam under uniform loading.

2. Bending moment:

$$M = Rx - \frac{wx^2}{2}. \tag{2a}$$

Designate x_0 as the location of the point of inflection. $0 < x_0 < a$. Therefore,

$$R = \frac{wx_0}{2} \tag{2b}$$

and

$$M = \frac{wx}{2}(x_0 - x). \tag{2c}$$

3. Shear force:

$$V = (R - wx) = w\left(\frac{x_0}{2} - x\right). \tag{3}$$

4. Bending stress:
Under the usual assumptions,

$$\sigma = \frac{Mc}{I}. \tag{4}$$

5. Shear stress:

Under the usual assumptions,

$$\tau = \frac{V}{ht_{\text{web}}}. \tag{5}$$

Choose t_{web} so that $\frac{|V|}{ht_{\text{web}}} = \tau_{sp}$ at all sections of the beam. Therefore it will not be necessary to consider this thickness any further. Equation 1 may now be written as:

$$W = \frac{8\rho}{h^2}\int_0^a I dx + \frac{2\rho}{\tau_{sp}}\int_0^a |V| dx. \tag{1a}$$

6. Maximum deflection location and magnitude:

Designate $\bar{x}$ as the coordinate location of the point of maximum deflection, $0 < \bar{x} < x_0$. It follows from the moment area theorems that:

$$\begin{gathered}\int_0^{\bar{x}} \frac{Mx}{EI} dx = \delta_{\max}, \qquad \int_{\bar{x}}^a \frac{M}{EI} dx = 0 \\ -\int_{\bar{x}}^a \frac{Mx}{EI} dx = \delta_{\max}, \text{ since } \int_0^a \frac{Mx}{EI} dx = 0.\end{gathered} \tag{6}$$

7. Weight function modified by constraining relations. Write:

$$\begin{aligned}W' = W + \lambda_1\left[\int_0^{\bar{x}} \frac{Mx}{EI} dx - (\delta_{sp} - \delta_0)\right] + \lambda_2 \int_{\bar{x}}^a \frac{M}{EI} dx \\ + \lambda_3 \int_0^a \frac{Mx}{EI} dx + \lambda_4[|M|c - I(\sigma_{sp} - \sigma_0)],\end{aligned} \tag{7}$$

where λ_1 to λ_4 are Lagrangian multipliers and $\delta_{sp} > \delta_0 \geqslant 0$; $\sigma_{sp} > \sigma_0 \geqslant 0$. Thus instead of minimizing W, the problem resolves itself into minimizing W'.

III. METHOD OF SOLUTION

The unknowns in the problem are $I = f(x)$, and the constants x_0, $\bar{x}$, λ_1 to λ_4. In order to determine these unknowns, it is necessary to use the calculus of variations to minimize the function W'. The variation of the function W' with respect to the function I must vanish, or $\frac{\partial W'}{\partial I}\delta I = 0$.

Since the integral limits are split, it is necessary to consider two regions of solution as follows:

$$(a)\quad 0 \le x \le \bar{x};\quad \frac{8\rho}{h^2} - \lambda_1 \frac{Mx}{EI^2} - \lambda_3 \frac{Mx}{EI^2} - \lambda_4(\sigma_{sy} - \sigma_0) \qquad (8a)$$

$$(b)\quad \bar{x} \le x \le a:\quad \frac{8\rho}{h^2} - \lambda_2 \frac{M}{EI^2} - \lambda_3 \frac{Mx}{EI^2} - \lambda_4(\sigma_{sy} - \sigma_0). \qquad (8b)$$

In addition:

$$\frac{\partial W'}{\partial \bar{x}} = 0 = \lambda_1 \left(\frac{M}{EI}\right)_{x=\bar{x}} - \lambda_2 \left(\frac{M}{EI}\right)_{x=\bar{x}}. \qquad (8c)$$

From Eq. 8*a* one may write:

$$(\sigma_{sy} - \sigma_0) = \frac{Mc}{I} = \frac{8\rho}{\lambda_4 h^2} - \frac{(\lambda_1 + \lambda_3)}{\lambda_4} \frac{Mx}{EI^2} = \sigma - \alpha \frac{Mx}{EI^2},\quad 0 \le x \le \bar{x}. \qquad (9a)$$

Similarly from Eq. 8*b* one may write:

$$(\sigma_{sy} - \sigma_0) = \frac{|M|c}{I} = \frac{8\rho}{\lambda_4 h^2} - \frac{\lambda_2}{\lambda_4}\frac{M}{EI^2} - \frac{\lambda_3}{\lambda_4}\frac{Mx}{EI^2}$$

$$= \bar{\sigma} - \bar{x}(\alpha - \beta)\frac{M}{EI^2} - \frac{\beta Mx}{EI^2}, \qquad (9b)$$

when $\bar{x} \le x \le a$, and where $\lambda_2 = \bar{x}\lambda_1$ from Eq. 8*c*.

When $x = x_0$, I is taken to be zero so that $\bar{x}(\alpha - \beta) + \beta x_0 = 0$, and β can be eliminated from Eq. 9*b*.

Equations 9 are quadratic in $\frac{M}{EI}$. With the aid of Eq. 2*c*, solution yields:

$$\frac{M}{EI} = \frac{(x_0 - x)}{k\alpha}\left[-1 + \sqrt{1 + \left(\frac{k\alpha}{x_0 - x}\right)}\right]\frac{2\bar{\sigma}}{Ec} \quad 0 \le x \le \bar{x} \qquad (10a)$$

$$\frac{|M|}{EI} = \frac{(x_0 - x)x}{k\alpha\bar{x}}\left[-1 + \sqrt{1 + \frac{k\alpha\bar{x}}{(x_0 - x)x}}\right]\frac{2\bar{\sigma}}{Ec} \quad \bar{x} \le x \le a, \qquad (10b)$$

where $k = \frac{8\bar{\sigma}}{wEc^2}$, $\bar{\sigma}$ being a stress scale factor determined by letting $\frac{Mc}{I} = \sigma_{sy}$ at some point.

IV. CALCULATIONS AND RESULTS

The unknowns in the problem now are $k\alpha$, x_0, and $\bar{x}$. These quantities are determined by satisfying simultaneously Eqs. 6. These equations are highly non-linear in the unknowns. However, actual

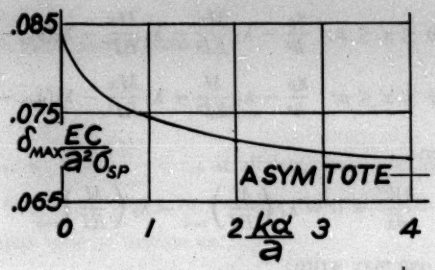

FIG. 2. Maximum beam deflection as a function of $\frac{k\alpha}{a}$.

calculations indicate that the values of x_0 and $\bar{x}$ are almost independent of $k\alpha$ and are: (For the sake of simplicity, no yielding is assumed to take place.)

$$x_0 = 0.41a,\ \bar{x} = 0.71a \text{ for } k\alpha = 0$$
$$x_0 = 0.42a,\ \bar{x} = 0.74a \text{ for } (k\alpha)^{-1} = 0. \tag{11}$$

Values of δ_{max} plotted *vs.* $\frac{k\alpha}{a}$, are shown in Fig. 2, and the distributions of the cap stresses are shown in Fig. 3 for several values of $\frac{k\alpha}{a}$. Notice

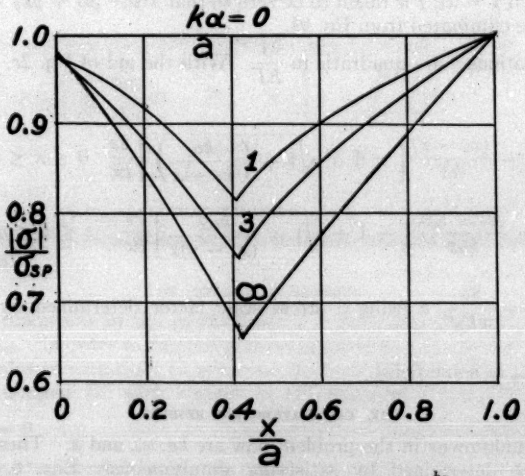

FIG. 3. Stress distributions for various values of $\frac{k\alpha}{a}$.

that δ_{max} approaches an asymptotic value for large values of $\frac{k\alpha}{a}$, and the maximum stress always occurs at $x = a$. Furthermore, for $k\alpha = 0$ the cap stress is constant throughout the beam.

It is seen from the curve in Fig. 2 that for $k\alpha = 0$

$$\delta_{max} = 0.084 \frac{a^2 \sigma_{sp}}{Ec}. \tag{12}$$

Thus if δ_{sp} is greater than or equal to this value, all cap material works at the same stress. However if δ_{sp} is less than the above value, then $k\alpha \neq 0$ and the stress distribution is no longer constant. It should be

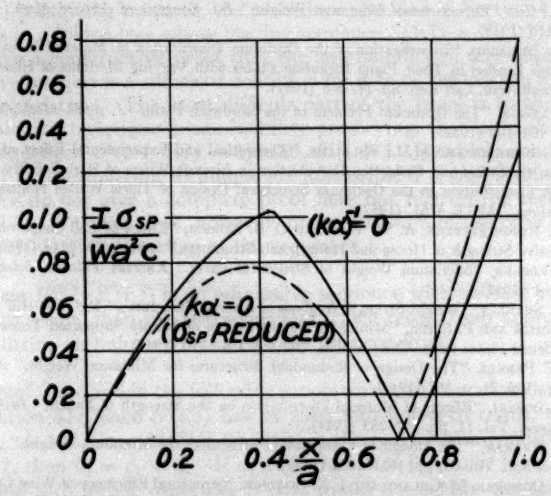

FIG. 4. Moment of inertia distributions for beams with equal maximum deflections.

realized that δ_{sp} always can be made equal to the above value by reducing the magnitude of σ_{sp}. The question now arises as to which design is more efficient, the one working at constant stress or the one with locally higher stress at $x = a$. Actual calculations indicate both types are equally efficient. This conclusion is borne out by the plots of moment of inertia distributions shown in Fig. 4. The solid curve is for $(k\alpha)^{-1} = 0$ with σ_{sp} the stress at $x = a$, and for which $\delta_{max} = 0.068 \frac{a^2 \sigma_{sp}}{Ec}$. In order to obtain the same deflection when all material works at the same stress, σ_{sp} must be reduced to $\frac{0.068}{0.084} \sigma_{sp}$. The dotted

curve represents the corresponding moment of inertia distribution in the beam. The areas under the two curves are found to be equal, that is, both beams weigh the same.

BIBLIOGRAPHY

(1) J. H. MEYER, "Test Development of Structures Designed Under Strength," *Aero. Eng. Rev.*, Vol. 13, p. 54 (1954).

(2) G. H. HEIMERL AND P. J. HUGHES, "Structural Efficiencies of Various Aluminum, Titanium, and Steel Alloys at Elevated Temperatures," NACA TN 2975 (1953).

(3) A. E. RUSSELL, "Aircraft Materials from the Designer's Point of View," Second Int. Aero. Conf., pp. 200–241 (1949).

(4) R. E. HUBKA, "Relative Structural Efficiencies of Flat Balsa Core Sandwich and Stiffened Panel Construction," NACA TN 2514 (1951).

(5) H. L. COX, "Structures of Minimum Weight," *Int. Congress of Applied Mech.*, Vol. 1, p. 416 (1948).

(6) P. P. BIJLAARD, "Investigation of the Optimum Distribution of Material in Sandwich Plates Loaded in Their Plane Including Plates with Varying Modulus of Elasticity," Cornell Aero. Lab Rep. SA-247-S-8 (1951).

(7) W. FLÜGGE, "The Optimum Problem of the Sandwich Plate," *J. Appl. Mech.*, Vol. 19, pp. 104–108 (1952).

(8) R. H. KORKEGI AND M. L. WILLIAMS, "Theoretical and Experimental Effect of Sweep upon the Stress and Deflection Distribution in Aircraft Wings of High Solidity. Part 17-A Contribution to the Optimum Structural Design of Thick Walled Hollow Wing Sections," AFTR 5761, (1952).

(9) L. A. RINGELSTETTER, A. W. VOSS AND C. B. NORRIS, "Effect of Cell Shape on Compressive Strength of Hexagonal Honeycomb Structures," NACA TN 2243 (1950).

(10) G. VEDELER, "Minimum Weight of Structural Parts," *Knorski Vidensk. Selsk. Skr.*, Vol. 1 (1951).

(11) F. R. SHANLEY, "Weight-Strength Analysis of Aircraft Structures," McGraw-Hill (1952).

(12) A. GOMZA AND P. SEIDE, "Minimum Weight Design of Simply Supported Transversely Stiffened Plates under Compression," NACA TN 1710 (1948).

(13) E. W. PARKES, "The Design of Redundant Structures for Minimum Weight," *Aircraft Eng.*, Vol. 21, p. 162 (1949).

(14) A. ZAHORSKI, "Effects of Material Distribution on the Strength of Panels," *Inst. Aero. Sciences*, Vol. 11, pp. 247–253 (1944).

(15) D. J. FARRAR, "The Design of Compression Structures for Minimum Weight," *J. Roy. Aero. Soc.*, Vol. 53, pp. 1041–1052 (1949).

(16) A. F. DONOVAN, M. GOLAND AND J. N. GOODIER, "Structural Efficiency of Wing Covers," *J. Appl. Mech.*, Vol. 67, p. A-8 (1945).

(17) E. H. SCHEUTTE AND J. C. MCCULLOCH, "Charts for the Minimum Weight Design of Multiweb Wings in Bending," NACA TN 1323 (1947).

(18) E. H. SCHEUTTE, "Charts for the Minimum Weight Design of 24S-T Aluminum Alloy Flat Compression Panels with Longitudinal Z Section Stiffeners," NACA TR 827 (1945).

(19) W. R. MICKS, "A Method of Estimating the Compressive Strength of Optimum Sheet-Stiffened Panels for Arbitrary Material Properties, Skin Thickness, and Stiffener Shapes," *Inst. Aero. Sciences*, Vol. 20, pp. 705–715 (1953).

(20) W. B. READEY, "Optimum Design of Indeterminate Frames," *Inst. Aero. Sciences*, Vol. 21, pp. 615–620 (1954).

(21) J. FOULKES, "Minimum Weight Design and the Theory of Plastic Collapse," *Quart. Appl. Math.*, Vol. 10, pp. 347–358 (1953).

(22) E. J. CATCHPOLE, "The Optimum Design of Compressive Surfaces Having Unflanged Integral Stiffeners," *J. Roy. Aero. Soc.*, Vol. 58, p. 800 (1954).

THE FOLDED TREE *

BY

ARTHUR W. BURKS,[1] ROBERT McNAUGHTON,[2] CARL H. POLLMAR,[1]
DON W. WARREN[1] AND JESSE B. WRIGHT[1]

Part II**

5. THE VALIDITY OF THE SPLITTING TECHNIQUE

In this section we show that, given any admissible n-term sequence $S'(1,1)$ containing no zeros, the procedure specified in Section 4 always results in a folded tree whose loading sequence $S(1,1) = S'(1,1)$. Thus we have a constructive proof that the admissibility of any sequence of positive integers is a sufficient condition for it to be the loading sequence of a folded tree. The most difficult part of the proof is to show that the splitting technique is admissibility-preserving, that is, to show that the sequences $S'(i + 1,2j - 1)$ and $S'(i + 1,2j)$ which result from $S'(i,j)$ by the splitting technique are admissible if $S'(i,j)$ is admissible.

(We do not give a complete proof here but rely on the results obtained in (4).[3] We shall, however, present enough of the proof to give an intuitive understanding of the argument.)

Theorem 10: If $S'(i,j)$ is an admissible sequence with at least two non-zero terms, then the two sequences which result from applying the splitting technique to it satisfy the unit condition.

Proof (here and in the following proofs we use the notation developed in Section 4): Since $S'(i,j)$ has at least two non-zero terms, d_1 must exist. $d_1 > 1$ since $M(S'(i,j))$ satisfies the partial sum condition. If $d_1 = 2$, then $b_1 = c_1 = 1$. If $d_1 > 2$, then $S'(i,j)$ cannot have exactly two non-zero terms, otherwise $S'(i,j)$ would not satisfy the total sum condition; hence, d_2 also exists and $c_1 = b_2 = 1$.

Theorem 11: Both of the sequences which result from applying the splitting technique to an admissible sequence satisfy the total sum condition.

---

* The writing of this paper and the research which it reports were done under the sponsorship of the Burroughs Corporation, Research Center, Paoli, Pa.

[1] The University of Michigan, Ann Arbor, Mich.

[2] Stanford University, Stanford, Calif.

** Part I appeared in this JOURNAL for July, 1955.

[3] The boldface numbers in parentheses refer to the references appended to Part I of this paper.

Proof: We need two lemmas.

Lemma 1. If $4 \leqq x \leqq p + 1$, then $\Delta_x = 0$ or 1; if $d_1 = 2$, then this is so for $x = 1,2,3$ as well.

The proof is by induction, and can be found on p. 33 of (4) (Lemma 1). (Note that "d_x" of this paper corresponds to "a_i" of (4).)

Lemma 2. $\Delta_{p+1} = 0$.

Proof: We show first that $\Delta_{p+1} = 0$ or 1. By Lemma 1 the only possible exceptions to this would be where $d_1 > 2$ and $p = 1$ or 2. If $p = 1$, then $d_1 = 2$, in order that $M(S'(i,j))$ satisfy the total sum condition. If $p = 2$, then $d_1 + d_2 = 6$ by the total sum condition. If $d_1 > 2$, then $d_1 = d_2 = 3$, since the d-sequence is monotonic non-decreasing. Here $c_1 = b_2 = 1$ and $b_1 = c_2 = 2$ so that $\Delta_2 = 0$. Having shown that in every case $\Delta_{p+1} = 0$ or 1, we must now show that the value is actually 0. As mentioned in the preceding section, for each x, $c_x + b_x = d_x$; hence,

$$\sum_{x=1}^{p} c_x + \sum_{x=1}^{p} b_x = \sum_{x=1}^{p} d_x.$$

But, since $M(S'(i,j))$ satisfies the total sum condition,

$$\sum_{x=1}^{p} d_x = 2^{p+1} - 2,$$

which is even. But Δ_{p+1} is precisely the difference between

$$\sum_{x=1}^{p} c_x \quad \text{and} \quad \sum_{x=1}^{p} b_x.$$

If Δ_{p+1} were 1, then their sum would have to be odd. Hence, $\Delta_{p+1} = 0$.

The theorem now follows directly. Since Lemma 2 entails that

$$\sum_{x=1}^{p} c_x \quad \text{and} \quad \sum_{x=1}^{p} b_x$$

are equal, it follows that

$$\sum_{x=1}^{p} d_x = 2 \sum_{x=1}^{p} b_x = 2 \sum_{x=1}^{p} c_x = 2^{p+1} - 2.$$

Hence,

$$\sum_{x=1}^{p} b_x = \sum_{x=1}^{p} c_x = 2^p - 1$$

and Theorem 11 is proved.

Theorem 12: If $b_1, \ldots, b_p$ and $c_1, \ldots, c_p$ are the sequences which result from the application of the splitting technique to an admissible

sequence $S'(i,j)$, then for every x such that $1 \leqq x \leqq p$,

$$\sum_{y=1}^{x} b_y \geqq 2^x - 1 \quad \text{and} \quad \sum_{y=1}^{x} c_y \geqq 2^x - 1.$$

This is proved as Lemma 3 on p. 34 of (4). (The "derived order," as the term is used in (4), is the order $b_1, b_2, \ldots, b_p$ and $c_1, c_2, \ldots, c_p$ as opposed to the monotonic order.) Roughly, Theorem 12 follows because $M(S'(i,j))$ satisfies the partial sum condition and the xth term of the b-sequence and the xth term of the c-sequence are usually obtained from the $(x+1)$st term of $M(S'(i,j))$ in such a way that

$$\sum_{y=1}^{x} b_y \text{ is nearly equal to } \sum_{y=1}^{x} c_y.$$

Thus, $\sum_{y=1}^{x} b_y$ is approximately $\frac{1}{2}\sum_{y=1}^{x} d_y$.

Since $1, d_1, \ldots, d_x$ are the first $x+1$ terms of $M(S'(i,j))$ and, since $S'(i,j)$ satisfies the partial sum condition,

$$1 + \sum_{y=1}^{x} d_y \geqq 2^{x+1} - 1$$

and hence

$$\tfrac{1}{2}\sum_{y=1}^{x} d_y \geqq 2^x - 1.$$

Theorem 13: If $S'(i,j)$ is admissible, then $S'(i+1,2j-1)$ and $S'(i+1,2j)$ satisfy the partial sum condition.

This is proved as Theorem 3 on p. 40 of (4). In order to prove Theorem 13 one must extend the result of Theorem 12; for the b-sequence and c-sequence are not always in monotonic non-decreasing order, and a sequence satisfying the summation condition of Theorem 12 may no longer satisfy it when monotonized. Fortunately, it can be proved that after the third term the b-sequence and c-sequence are each, in the terminology of (4), quasi-monotonic, that is, for any x and x', if $4 \leqq x < x' \leqq p$, then $b_x \leqq b_{x'} + 1$ and $c_x \leqq c_{x'} + 1$. It is rather easy to show by virtue of this fact and Theorem 12 that, for each x,

$$\sum_{y=1}^{x} b'_y \geqq 2^x - 1,$$

where $b'_1, \ldots, b'_p$ is monotonic after the third term and results from $b_1, \ldots, b_p$ by interchanging the appropriate terms after b_3; similarly

for the c-sequence. (Cf. the theorem on p. 18 of (4).) The extension of this result to the case where the first three terms are rearranged to make the entire sequence monotonic is made in the proof in (4).

Theorem 14: For every $i < n$, if $S'(i,j)$ has n terms including exactly $i - 1$ zero terms and is admissible, and if $S'(i + 1,2j - 1)$ and $S'(i + 1,2j)$ are obtained from $S'(i,j)$ by the splitting technique, then $S'(i + 1,2j - 1)$ and $S'(i + 1,2j)$ are admissible and each contains exactly i zeros.

Proof: That these are admissible follows from Theorems 10, 11, and 13. $S'(i + 1,2j - 1)$ differs from $b_1, \ldots, b_p$ in at most the presence of zeros and the order of terms, which does not affect admissibility; similarly for $S'(i + 1,2j)$ and $c_1, \ldots, c_p$. To prove that they each have i zeros, it suffices to prove that there is one and only one unit term in $S'(i,j)$. That there is one follows from the fact that $S'(i,j)$ satisfies the unit condition. That there is only one follows from the fact that $S'(i,j)$ satisfies the partial sum condition; for if there were at least two, then the sum of the first two terms of $M(S'(i,j))$ would be $2 < 2^2 - 1$.

Theorem 15: Given $S'(1,1)$ as an admissible n-term sequence without zeros, the procedure specified in Section 4 results in an n-bay folded tree whose $S(1,1) = S'(1,1)$.

Proof: From Theorem 14 it follows that for any $j < 2^{n-1}$ the sequence $S'(n,j)$ has $n - 1$ zeros and is admissible. Its one non-zero term, say, a_k, must be unity by the total sum condition, and so $V(n,j)$ is labeled P_k. Therefore, (1) $S'(n,j)$ is $S(n,j)$ and $T(n,j)$ is a folded tree.

We now go on to prove that (2) for any i and j, if $S'(i + 1,2j - 1)$ is $S(i + 1,2j - 1)$ and $S'(i + 1,2j)$ is $S(i + 1,2j)$, and if $T(i + 1,2j - 1)$ and $T(i + 1,2j)$ are folded trees, then $S'(i,j)$ is $S(i,j)$ and $T(i,j)$ is a folded tree. There is a set

$$\{P_{m_1}, \ldots, P_{m_{n-i}}\}$$

of $n - i$ distinct labels such that each chain of $T(i + 1,2j - 1)$ contains exactly one vertex labeled with each member of the set. The m_1th, $\ldots$, m_{n-i}th terms of $S(i + 1,2j - 1)$, which is $S'(i + 1,2j - 1)$, are exactly those terms which are non-zero terms. There is a similar set for $T(i + 1,2j)$. Now this set is identical to the set for $T(i + 1, 2j - 1)$, since for any q the qth term of $S'(i + 1,2j - 1)$ will be made zero by the splitting technique if and only if the qth term of $S'(i + 1,2j)$ is made zero. If $V(i,j)$ is labeled P_k, then k is not one of the $m_1, \ldots, m_{n-i}$; this is so because the kth term of $S'(i,j)$ is one and, therefore,

the kth term of $S'(i + 1,2j - 1)$ and the kth term of $S'(i + 1,2j)$ are each zero. From this it follows that every chain of $T(i,j)$ has exactly one vertex labeled with each member of the set

$$\{P_k, P_{m_1}, \ldots, P_{m_i}\},$$

since a chain of $T(i,j)$ is either a chain of $T(i + 1,2j - 1)$ or a chain of $T(i + 1,2j)$ with $V(i,j)$ and its vertex-input added. Hence $T(i,j)$ is a folded tree. Now each term of $S'(i,j)$, except $a'_k(i,j) = 1$, is equal to the sum of the corresponding terms of $S'(i + 1,2j - 1)$ and $S'(i + 1, 2j)$; $a'_k(i + 1,2j - 1) = a'_k(i + 1,2j) = 0$. (This follows from the specification of the splitting technique.) Since the vertices of $T(i,j)$ are those of $T(i + 1,2j - 1)$ and $T(i + 1,2j)$ together with $V(i,j)$, it follows, from the fact that $S'(i + 1,2j - 1)$ is $S(i + 1,2j - 1)$ and $S'(i + 1,2j)$ is $S(i + 1,2j)$, that $S'(i,j)$ is $S(i,j)$.

From (1) and (2) it follows immediately by induction that $S'(1,1)$ is $S(1,1)$ and $T(1,1)$ is a folded tree.

6. THE ECONOMY OF THE FOLDED TREE

The question arises as to whether circuits represented by folded trees are the most "economical" ones which can function as complete decoding circuits. As we have indicated earlier (Section 2) the answer is in the negative so far as electronic digital computing circuits are concerned (see also Section 5 of (2)). However, folded tree relay transfer contact nets are probably the most economical (in a sense to be defined) of all complete decoding relay transfer contact nets. To formulate this proposition precisely we must delimit the class of diagrams whose realizations are all such complete decoding relay transfer contact nets.

Our definition of vertex diagram at the beginning of Section 2 was motivated by two considerations: (1) that a relay transfer contact is well represented by a vertex with a single vertex-input and two vertex-outputs, and (2) that in a relay transfer contact net the relay transfer contacts can be arbitrarily connected. Hence any relay transfer contact net can be represented by some vertex diagram. In this section we go on to define an n-label complete decoding vertex diagram in such a way that every transfer contact net which performs a complete decoding function is represented by a diagram of this kind. Our belief that folded tree relay transfer contact nets are probably the most economical of all complete decoding relay transfer contact nets can now be more precisely stated as the conjecture: The n-bay folded tree has the minimal number of vertices of any n-label complete decoding vertex diagram.

The objection may be made that the minimality of the number of vertices of a complete decoding vertex diagram is not a sufficient condition for its realization by relays to be minimal in cost, for the cost of a relay transfer contact net depends not only on the number of

transfer contacts in it but also on the number of relay coils required to operate it. To particularize this objection, consider the problem of constructing a complete decoding net using only relays with eight transfer contacts each; here the number of relays required is a better indication of the cost of the net than the number of transfer contacts it contains.

There is a certain force to this objection. However, it is to a large extent mitigated by our previous folding results. For if an n-bay standard tree circuit has a minimal number of contacts, we can in practice use that folded tree circuit which of all n-bay folded trees has the least number of relay coils. For an example see the last part of Section 2. When relays with different numbers of contacts are available at costs which are not directly proportional to the number of contacts they contain, then a different folding can be employed to minimize the total cost of the circuit.

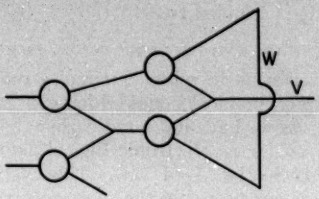

FIG. 9.

We have not proved our minimality conjecture, but in this section we present a partial result in that direction. To this end we will introduce a certain subclass of the class of n-label complete decoding vertex diagrams, namely, the subclass of all n-label progressive diagrams. We shall prove that the n-bay folded tree has the minimal number of vertices of an n-label progressive diagram. It seems, intuitively, that an n-label complete decoding vertex diagram which is not an n-label progressive diagram should have at least as many vertices as an n-bay folded tree, and it is on this ground that we make our conjecture.

We now proceed to carry out the program sketched above. Since all the vertex diagrams considered in previous sections were trees, we first present an example of a vertex diagram that is not a tree (Fig. 9). (Note the use of the loop in the wire W of Fig. 9 to indicate that the wire W does not touch the wire V.)

Some of the concepts already introduced in connection with trees must be generalized to apply to arbitrary vertex diagrams. First, we require a more general method of describing the way states of wires are determined. To accomplish this we define the notion of the connection of two wires.

We say that two wires are *directly connected* when they touch each other. A vertex is *directly connected* to a wire whenever the wire is either its vertex-input, or its upper (lower) vertex-output when the vertex is in the upper (lower) setting. Two wires W and W' are *connected* if there is a sequence of wires and vertices $X_1, \ldots, X_n (n \geqq 1)$ such that W is X_1, W' is X_n, and such that, for each $i < n$, X_i is directly connected to $X_i + 1$. By taking $n = 1$ we see that any wire is always connected to itself. The sequence $X_1, \ldots, X_n$ is a *connection* of W and W'. Thus, whether two wires in a diagram are connected usually depends upon the settings of some of the vertices of the diagram.

An *n-label complete decoding vertex diagram* (with designated diagram input and diagram outputs) is a vertex diagram in which the following hold.

1. Each vertex V has exactly one label from a set of n distinct labels.
2. For each label there is at least one vertex with that label.
3. There is exactly one wire K designated as the *diagram input*.
4. A *diagram state* is a definite assignment of the vertex settings such that (*a*) all the vertices with the same label are set the same, and (*b*) a wire is in state 1 if and only if it is connected to the diagram input.
5. For each diagram state, there is at least one wire which is in state 1 in that diagram state and in state 0 in every other diagram state, and for each diagram state one such wire is designated (arbitrarily, if there is more than one) as a *diagram output* of the diagram.

The diagram input is in state 1 in any diagram state since it is always connected to itself. Since there are n labels for the vertices, there are 2^n diagram states, and, therefore, 2^n diagram outputs. For any diagram output Q, let $S(Q)$ be the diagram state in which Q is in state 1.

Sometimes in these diagrams a vertex may have the state of its vertex-input depend on the state of one of its vertex-outputs. For example, consider the uppermost vertex of Fig. 10. When it is in its lower setting, the state of its vertex input Q_2 depends upon the state of its lower vertex output. For this reason the terms "vertex-input" and "vertex-output" are not as appropriate for the more general class of vertex diagrams as they are for the class of trees.

Obviously, trees are vertex diagrams, and by Theorem 1 n-bay folded trees are complete decoding n-label vertex diagrams.

For an arbitrary connection $X_1, \ldots, X_p$, if X_k is directly connected to X_m for $m > k + 1$, then $X_{k+1}, \ldots, X_{m-1}$ are *superfluous;* the sequence with them deleted is still a connection. It is easy to see, therefore, that in a diagram state, S, if there is a connection between W and W', then there is a connection between them in S without any

superfluous vertices or wires. A *chain* of a diagram output Q is a sequence $X_1, \ldots, X_p$ of wires and vertices which in $S(Q)$ is a connection of the input K and Q without any superfluous elements. Obviously, the chain as defined in Section 2 is a chain in this sense.

If $X_1, \ldots, X_m$ is a chain C (where X_1 is the diagram input K and X_m is a diagram output), then for any i,j such that $i < j$ we say that X_i is *earlier* than X_j in C. If X_i is a vertex, then X_{i-1} and X_{i+1} are wires of the vertex, one being the vertex-input of X_i and the other being one of the vertex-outputs of X_i; we say that X_{i-1} is the *early wire* and X_{i+1} the *late wire* of the vertex X_i in the chain C. If the early wire of a vertex in a chain is the vertex-input, then we say the vertex is oriented *forward* in the chain; if the early wire is a vertex-output, then the vertex is oriented *backward*. For example, the vertices labeled P_2 in the chains of Q_1 and Q_3 in Fig. 10 are backward, whereas the vertex

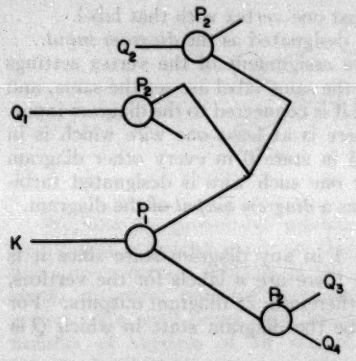

FIG. 10.

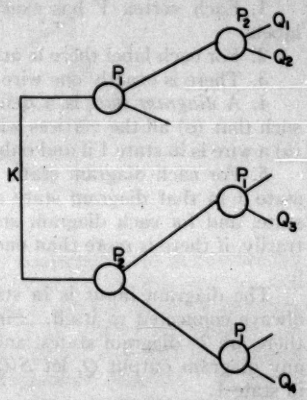

FIG. 11.

labeled P_2 in the chains of Q_3 and Q_4 is forward in both those chains. The vertex labeled P_1 is forward in all chains.

A *progressive diagram* is a complete decoding vertex diagram in which each output Q has at least one chain in which all vertices are forward. The folded tree is a progressive diagram while Fig. 10 is a complete decoding vertex diagram which is not progressive.

An output Q of a progressive diagram may have more than one chain in which all vertices are forward. It is convenient to pick out for each output Q of a progressive diagram one such chain and refer to it as $C(Q)$, or the *selected chain* of the output.

Where Q and Q' are two distinct diagram outputs of a complete decoding vertex diagram, we define $V(Q,Q')$ to be the latest vertex V

in $C(Q)$ whose early wire is in state 1 in $S(Q')$ and whose late wire is in state 0 in $S(Q')$. Such a vertex must exist since the diagram input K is in state 1 in $S(Q')$ but Q is in state 0 in $S(Q')$; the latest wire of $C(Q)$ which is in state 1 in $S(Q')$ must be the early wire of a vertex in $C(Q)$. For example, in Fig. 11 $V(Q_1,Q_4)$ is the vertex labeled P_1 in $C(Q_1)$ and $V(Q_4,Q_1)$ is the vertex labeled P_2 in $C(Q_4)$. This example shows, incidentally, that $V(Q,Q')$ and $V(Q',Q)$ are not always identical.

Whenever A is any set of outputs of a progressive diagram we let $D(A)$ be the set of just those vertices $V(Q,Q')$ where Q and Q' are both in A. If A has only one output Q, then $D(A)$ is the null set, since there is no $V(Q,Q)$. For any set A and any output Q not in A, $A + \{Q\}$ is the set whose members are Q and all the members of A.

Theorem 16: If A is a set of one or more outputs of a progressive diagram, and if Q is an output not in A, then there is a vertex in $D(A + \{Q\})$ which is not in $D(A)$.

Proof: Let V be the latest vertex $V(Q,Q')$ in $C(Q)$ where Q' is in A. We shall prove that V is not in $D(A)$, from which Theorem 16 follows directly since V must be in $D(A + \{Q\})$.

We shall use the *reductio ad absurdum* method. Suppose that V is in $D(A)$. Then there are diagram outputs Q'' and Q''' in A such that V is $V(Q'',Q''')$. Let x be the early wire of V in $C(Q)$ and y the late wire. Since the diagram is progressive and since V is in $C(Q)$, x is the vertex-input and y is a vertex-output of V. Let z be the other vertex-output of V. Since V is $V(Q'',Q''')$, x is in $C(Q'')$ and either y or z is in $C(Q'')$.

Case I. y is in $C(Q'')$. Then y is in state 1 in $S(Q'')$. The latest wire in $C(Q)$ which is in state 1 in $S(Q'')$, then, can be no earlier than y, and hence $V(Q,Q'')$ is later than V in $C(Q)$, contrary to the original stipulation that V be the latest such vertex in $C(Q)$.

Case II. z is in $C(Q'')$. Since V is $V(Q'',Q''')$, x must be in state 1 in $S(Q''')$, and z in state 0. This means that the setting of the vertex V in $S(Q''')$ must be such that y is in state 1 in $S(Q''')$. Reasoning as in Case I, then, we can show that $V(Q,Q''')$ is later than V in $C(Q)$, which is likewise contradictory. This completes the proof of Theorem 16.

Theorem 17: In a progressive diagram, if A is a set of k outputs then there are at least $k - 1$ vertices in $D(A)$.

Proof: Let $A_2, \ldots, A_k$ be a sequence of subsets of A such that A_k is A, A_i has exactly i members, and, if $2 \leqq i \leqq k - 1$, A_i is a proper subset of A_{i+1}. Thus, A_{i+1} has just one member besides those of A_i. There is at least one vertex in $D(A_2)$; and by Theorem 16 $D(A_{i+1})$ has

at least one more vertex than $D(A_i)$. Hence, $D(A_k)$ has at least $k - 1$ vertices.

Theorem 18: In the class of n-label progressive diagrams the n-bay folded tree has a minimal number of vertices.

Proof: In an n-label complete decoding vertex diagram there are 2^n outputs. If A is the set of all these outputs, then $D(A)$ must have at least $2^n - 1$ vertices. Hence, the diagram must have at least $2^n - 1$ vertices which is the number of vertices in the n-bay folded tree.

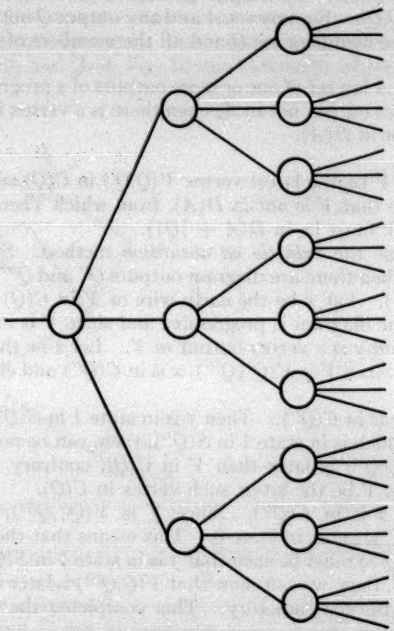

FIG. 12.

7. A GENERALIZATION OF THE FOLDED TREE

In this section we shall consider generalized folded trees containing vertices, all of which have the same arbitrary number of vertex outputs and possible settings. A vertex with m vertex-outputs is called an m-order vertex and its m settings are the first setting, the second setting, . . . , the mth setting. The ith *vertex output* is the ith right-hand wire from the top. (See Fig. 12.)

A generalized n-bay folded tree containing vertices of order m,

called an n-bay *m-order folded tree*, obviously contains

$$\sum_{x=1}^{n} m^{x-1} = (m^n - 1)/(m - 1)$$

vertices. Thus an n-bay folded tree as previously defined has order 2. The definition of "complete decoding" is the same as that given in Section 2, and the generalization of Theorem 1 goes through quite easily.

It is not difficult to see what sort of physical realization an m-order vertex can have, either in relay circuits or in electronic digital computing circuits. In relay circuits the m-order vertex represents a single-pole m-throw switch, for example, a stepping switch. In electronic digital computing circuits the m-order vertex can represent an arrangement of m conjunction elements generalized from the arrangement of Fig. 2.

As in Section 2 we ask the question, for a given loading sequence, $a_1, \ldots, a_n$, is there an n-bay m-order folded tree having a_1 vertices labeled $P_1, \ldots$, and a_n vertices labeled P_n? We have a generalized condition of "admissibility" which we can prove to be necessary and which we conjecture to be sufficient if the sequence contains no zeros. Our generalized condition of admissibility involves four conditions, as compared with only three in Section 3.

A sequence satisfies the *unit condition* if there is a 1 somewhere in the sequence. It satisfies the *total sum condition* if the sum of all the terms is equal to

$$(m^p - 1)/(m - 1) = \sum_{x=1}^{p} m^{x-1}$$

where p is the number of non-zero terms. A sequence S satisfies the *partial sum condition* if, for each $k \leqq p$, the sum of the first k terms of $M(S)$ is greater than or equal to

$$(m^k - 1)/(m - 1) = \sum_{x=1}^{k} m^{x-1}.$$

It satisfies the *congruence condition* if, for each term a_k, $a_k \equiv 1 \pmod{m-1}$, that is, $a_k - 1$ is divisible by $m - 1$. A sequence is *admissible* if it satisfies all four conditions. Note that admissibility as defined in Section 3 is a special case ($m = 2$) of this more general notion of admissibility, for any sequence of integers satisfies the congruence condition when $m = 2$.

Theorem 19: The loading sequence $S(1,1)$ of an n-bay m-order folded tree is an admissible sequence of n non-zero terms.

Proof: Obviously, $S(1,1)$ must satisfy the unit condition and the total sum condition. The reader can reread Theorem 8 and its proof and see that it very easily generalizes from the case ($m = 2$) to prove that $S(1,1)$ satisfies the partial sum condition for any m. To demon-

strate that $S(1,1)$ satisfies the congruence condition we consider any n-bay m-order folded tree having $a_k(1,1)$ vertices labeled P_k. Suppose that for each $h \leqq n$ there are k_h vertices labeled P_k in the hth bay. There are m^n chains and each chain must have exactly one vertex labeled P_k.

But a vertex in the hth bay is on exactly m^{n-h+1} chains. Hence (1) the number of chains is equal to

$$\sum_{h=1}^{n} k_h m^{n-h+1} = m^n.$$

By elementary number theory we know that for any non-negative integer x, $m^x \equiv 1 (\text{mod } m-1)$. Thus, for each h, $k_h m^{n-h+1} \equiv k_h (\text{mod } m-1)$. Hence (2)

$$\sum_{h=1}^{n} k_h m^{n-h+1} \equiv \sum_{h=1}^{n} k_h (\text{mod } m-1).$$

From (1) and (2), since $m^n \equiv 1 (\text{mod } m-1)$, it follows that

$$a_k(1,1) = \sum_{h=1}^{n} k_h \equiv 1 (\text{mod } m-1).$$

This completes our proof of Theorem 19.

APPENDIX

Interchange and the Folded Tree

The phrase "folded tree" is appropriate because a folded tree can be obtained from the standard tree of Section 2 by the technique of "folding." That technique, perhaps better described as "interchange," can be defined as follows. An n-bay labeled-tree $T'(1,1)$ results from an n-bay labeled-tree $T(1,1)$ by an *interchange* of P_h and P_k in the minor tree $T(i,j)$ when all the vertices labeled P_h in $T(i,j)$ are labeled P_k in $T'(i,j)$ and vice versa, all other vertices of $T'(1,1)$ being labeled the same as in $T(1,1)$.

By referring to the definition of "folded tree," it is not difficult to see (1) that if $T'(1,1)$ is obtained from $T(1,1)$ by interchange, then $T'(1,1)$ is a folded tree if and only if $T(1,1)$ is.

It can also be shown (2) that for any n-bay folded trees $T(1,1)$ and $T'(1,1)$ having the same set of labels, $T'(1,1)$ can be obtained from $T(1,1)$ by a sequence of interchanges. For suppose $T_1(1,1)$, $T_2(1,1)$, . . . , is a sequence of distinct n-bay labeled-trees where $T_1(1,1)$ is $T(1,1)$ and where $T_{s+1}(1,1)$ is obtained from $T_s(1,1)$ by the following process. Having ordered all the vertices of $T_s(1,1)$ in the sequence $V_s(1,1)$, $V_s(2,1)$, $V_s(2,2)$, $V_s(3,1)$, $V_s(3,2)$, . . . , we consider the first vertex $V_s(i,j)$ which has a label different from the corresponding vertex $V'(i,j)$ of $T'(1,1)$. Suppose that P_h and P_k are the labels of $V_s(i,j)$ and $V'(i,j)$, respectively. Then $T_{s+1}(1,1)$ results from $T_s(1,1)$ by interchange of P_h and P_k in $T_s(i,j)$. It is easily seen that P_k must label at least two vertices in $T_s(i,j)$, so the interchange can always be made if $T_s(1,1)$ is not identical with $T'(1,1)$. Obviously, then the label of $V_{s+1}(i,j)$ and the labels of all vertices of $T_{s+1}(1,1)$ which precede $V_{s+1}(i,j)$ in the ordering of vertices mentioned above are the same as the labels of the corresponding vertices of $T'(1,1)$. It is not difficult to see that the sequence $T_1(1,1)$, $T_2(1,1)$, . . . has a last member $T_q(1,1)$ which must be $T'(1,1)$.

Since a standard tree is a folded tree, it follows from (1) and (2) that a necessary and sufficient condition that an n-bay labeled-tree with labels $P_1, \ldots, P_n$ be a folded tree is that it be obtainable from the n-bay standard tree by a sequence of interchanges.

Everything asserted in this appendix is true also of trees all of whose vertices are of order $m > 2$.

NOTE ON "UPWARD STEPPED LEADERS FROM THE EMPIRE STATE BUILDING"

BY

C. E. R. BRUCE[1]

In a note (1)[2] with the above title Schonland and Malan suggest that lightning flashes from the Empire State Building may in fact always be initiated by upward *negative* leaders from the Building, and not, as has hitherto been assumed, by upward *positive* leaders. Were it otherwise, "this would mean that the parameters involved in the propagation of stepped leader streamers are exactly the same whether the streamers are positive or negative, a conclusion so unusual and unexpected as to need careful scrutiny."

However, the writer would like to suggest that the authors' suggestion in its turn requires careful scrutiny.

It would appear that there are two main considerations which render it unlikely that all the flashes photographed by McEachron were initiated by upward *negative* leaders. The first is the relative ease with which positive streamers are initiated relative to negative streamers, and the second is the fact that the Empire State Building trips off discharges in average fields which are very small relative to those required for normal cloud to earth flashes. This is apparent, as was emphasized earlier (2), from the exceptionally high number of flashes which occur to the Building, as many as nineteen or more in *one day*. It causes such a concentration of electric field at its top that, even with an average field of only 50 V/cm near the ground, the potential of its top relative to the surrounding space reaches values of the order of 2×10^6 V, a value which the writer suggested (3) is probably sufficient to initiate the transition to arc conditions (that is, thermal ionization) in the corona discharge, and the onset of a self-propagating discharge.

One would thus expect the Building's ability to trip off a flash to be independent of the presence overhead of the relatively small concentration of positive charge, which has dimensions of the order of only 1·km (4), compared with those of the order of 10 km or more of the lower negative charge (2). From the diagrams of the charge distribution in thunderclouds in the papers by Simpson and his collaborators at Kew, it would appear that the Building is more likely to have a field at its tip which is mainly governed by the lower negative charge than by the small

[1] The Electrical Research Association Laboratories, Perivale, Greenford, Middlesex, England.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

concentrated positive charge. From Simpson and Robinson's diagram of the charge distribution (their Fig. 1 (4b)), it will be seen that the area at the ground under a thunder cloud throughout which the electric field is negative, is about 60 times the area throughout which it is positive. The authors' Fig. 1 is misleading in this respect, and a more realistic picture is obtained by superimposing an Empire State Building on Simpson and Scrase's diagram (4a), as is done in Fig. 1. This conclusion is supported by Pierce's observation (5) that, in contrast to thunderstorm conditions in South Africa (6), storms in Great Britain, and presumably in temperate regions generally, tend to develop the lower negative charge in concentrations at the same height.

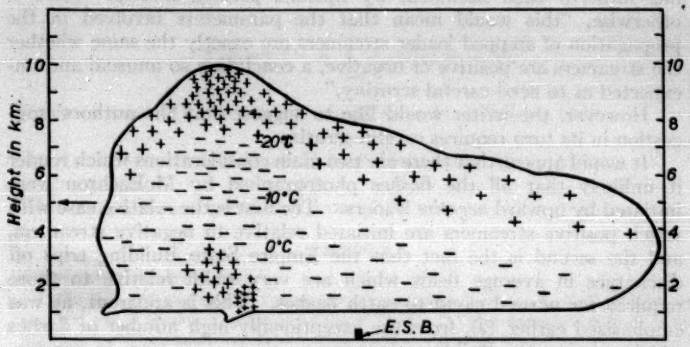

FIG. 1.

However, in view of the desirability of having this important question cleared up the writer would like strongly to supplement the authors' plea that more work should be done on the study of lightning to the Empire State Building. It is a plea that he himself made many years ago (3).

REFERENCES

(1) B. F. J. SCHONLAND AND D. J. MALAN, JOUR. FRANKLIN INST., Vol. 258, p. 271 (1954).
(2) C. E. R. BRUCE AND R. H. GOLDE, *J. I. E. E.*, Vol. 88 (II), p. 487 (1941).
(3) C. E. R. BRUCE, *Proc. Roy. Soc. A.*, Vol. 183, p. 228 (1944).
(4) (a) G. C. SIMPSON AND F. J. SCRASE, *Proc. Roy. Soc. A.*, Vol. 161, p. 309 (1937).
(b) G. C. SIMPSON AND W. ROBINSON, *Proc. Roy. Soc. A.*, Vol. 177, p. 281 (1941).
(5) E. T. PIERCE, Thesis, Cambridge, 1950, and *Quart. Jour. Roy. Met. Soc.*, Vol. 81, p. 211 (1955).
(6) D. J. MALAN AND B. F. J. SCHONLAND, *Proc. Roy. Soc. A.*, Vol. 206, p. 145 (1951).

NUCLEAR ENERGY NEWS

ACCESS PERMITS AND "L" CLEARANCE

The Atomic Energy Commission has announced new regulations that will greatly facilitate the dissemination of information relating to civilian uses of atomic energy. These regulations are intended to carry out some of the stated purposes of the 1954 Atomic Energy Act with reference to encouraging scientific and industrial progress. They make possible widespread participation in the development and utilization of atomic energy for peaceful purposes to the maximum extent consistent with the common defense and security and with the health and safety of the public.

One part of the new regulations sets up a new type of clearance—designated "L"—which is much quicker and easier to obtain than the "Q" clearance regularly used by the AEC. Another part of the new regulations establishes procedures and criteria for granting permits for access to confidential and secret "Restricted Data" relating to civilian uses of atomic energy. "Restricted Data" which is primarily of military significance is not within the scope of this program. The new system of Access Permits will liberalize the previous program of limited study agreements that has been in operation for the past several years.

Under the Access Permit program confidential "Restricted Data" may be made available to any person who can show a potential use or application of the information in his business, profession, or trade. However, secret "Restricted Data" may only be made available to persons evidencing a need, limited to a definite period of time, for specific information having an immediate or significant effect upon their business, profession, or trade.

Each individual who is to receive confidential "Restricted Data" pursuant to an Access Permit must obtain an "L" clearance. "Q" clearances are necessary to receive secret "Restricted Data." The security regulation prohibits the transfer of secret information from one organization to another without authorization from the Commission, whereas, confidential information in the peacetime areas can be transferred within or outside an organization to any appropriately cleared person.

The Commission will waive, under section 152 of the Act, all rights in inventions and discoveries resulting from access to "Restricted Data" pursuant to the Access Permit except that the Commission will reserve a royalty-free, non-exclusive license for Governmental purposes only in inventions resulting from access to secret "Restricted Data" under the permit.

The holder of an Access Permit, in turn, will waive certain specified claims against the Commission for damage and just compensation, will agree to conform to applicable security regulations and to pay established charges for publications and services obtained from the Commission and for personnel security clearances.

The Access Permits are administered by the Director of the Division of Licensing of the AEC, from whom applications for these permits can be obtained.

REACTOR FOR SWITZERLAND

Representatives of the Governments of Switzerland and the United States initialed on June 10 an agreement for cooperation covering the sale and purchase of the research reactor that is to be a central feature of the official U. S. exhibit at the United Nations' International Conference on Peaceful Uses of Atomic Energy at Geneva in August.

The reactor, which is to be assembled from components shipped to Geneva from Oak Ridge, will be in operation as a part of the official U. S. exhibit while the conference is in session August 8–20. At the conclusion of the conference the U. S. Government, through the Atomic Energy Commission, will sell the reactor to Switzerland.

The price of the reactor, building, associated machinery and exhibits is to be $180,000. The U. S. will lease to Switzerland sufficient uranium enriched in the isotope U-235 for initial and replacement fuel for the reactor. The quantity of uranium under such lease shall not contain more than six kilograms of U-235 (maximum enrichment—20 per cent), plus such additional quantity as the AEC may determine is necessary to permit the efficient and continuous operation of the reactor while replaced fuel elements are radioactively cooling in Switzerland or while fuel elements are in transit.

The agreement included the following provisions:

The reactor shall be used solely for research purposes related to the development of the peaceful, beneficial and humanitarian uses of atomic energy.

No material transferred to Switzerland under the agreement will be used for atomic weapons or for research on or development of atomic weapons or for any other military purposes, and none will be transferred to unauthorized persons or beyond the jurisdiction of the Government of Switzerland.

Restricted Data shall not be communicated under the agreement.

The AEC will exchange with Switzerland information relating to (a) design, construction and operation of the reactor and its use as a research tool; (b) health and safety problems in the operation and use of the reactor; (c) the use of radioactive isotopes produced in the reactor and (d) power levels of the reactor's operation and burn-up of reactor fuels.

Subject to availability of supply, the AEC will sell or lease to Switzerland such reactor materials, other than special nuclear materials, as are not obtainable on the commercial market and which are required in operation of the reactor.

The agreement is for a five-year period and shall be renewed automatically for another five years unless terminated with due notice by either party. At the expiration of the agreement the Government of Switzerland is to deliver to the U. S. all fuel elements or other fuel material leased from the AEC.

Under the provisions of the U. S. Atomic Energy Act of 1954 certain procedural steps must be taken by the Executive and Legislative branches of the United States of America before the agreement may be signed and entered into force.

ELECTRIC POWER FROM EXPERIMENTAL REACTOR

The Atomic Energy Commission has invited proposals by public, cooperative, or private organizations to purchase the heat produced in experimental operation of the sodium graphite reactor now under construction at a site 30 miles northwest of downtown Los Angeles, California. As required by the Atomic Energy Act of 1954, the AEC will give preference and priority to public bodies and cooperatives in contracting for the disposal of heat energy produced by the reactor.

The reactor, known as the Sodium Reactor Experiment (SRE), is one of five reactor systems with which the AEC is currently experimenting in its program for the development of economically competitive nuclear power. The development work and fabrication of the reactor is being done by North American Aviation, Inc., under contract with the AEC. North American is bearing about 25 per cent of the cost of the experiment and will operate the plant when it is completed in 1956.

As originally planned the SRE was not to be equipped with a turbo-generator for the production of electricity. The primary objective of the experiment is to develop the technology of reactors utilizing sodium as the cooling agent and graphite as the moderator. The heat generated by the experiment will be removed from the reactor by a primary liquid sodium circuit which will become radioactive in passing through the reactor core. The heat in the primary system will be transferred in an intermediate heat exchanger to a secondary sodium system which will not become radioactive.

The peak heat load of the SRE will be about 20,000 kilowatts, permitting the generation of approximately 7500 kilowatts of electricity. The availability of heat from the reactor will be subject to the demands of the experimental program and therefore no guarantee can be given of the quantity or continuity of energy from the SRE. Despite the unfirm nature of the energy it is believed that valuable operating experience can be gained by generating electric power.

ENGINEERING TEST REACTOR

The U. S. Atomic Energy Commission has entered into a contract with the Henry J. Kaiser Company, Kaiser Engineers Division, Oakland, California, for architect-engineering of an Engineering Test Reactor after consideration of a list of 29 companies. Work under the contract, which will include nuclear design, has been started at the company's Oakland office. This contract with Kaiser Engineers parallels a previously announced procedure under which the Commission has invited proposals from industry to build and operate an Engineering Test Reactor with private funds. (See this JOURNAL, Vol. 260, p. 47.)

The reactor will provide certain radiation facilities the Commission will need for the development of cores, fuel assemblies, and other components. Irradiation facilities now available to the AEC are not adequate for engineering experiments which require relatively large spaces in areas with high neutron intensities. It is expected that during the early years of the ETR's operation much of the reactor's capacity will be used for AEC projects related to requirements of Air Force, Army and Navy and for development of civilian nuclear power.

The AEC has specified that to meet its needs, operation of the reactor at design characteristics must begin by March 1957.

DUAL-CYCLE BOILING REACTOR FOR POWER

Design of a new atomic power reactor has been announced by the General Electric Company. One of these new dual-cycle boiling reactors will power the proposed full-scale nuclear electric generating station that G. E. will construct, subject to AEC approval of the project, for the Commonwealth Edison Company near Chicago, Illinois.

Plans for the plant set the generating capacity at 180,000 kilowatts, the largest all-nuclear station yet scheduled. The plant will be located on a 750-acre site near the confluence of the Kankakee and Des Plaines rivers in Grundy County, Ill. It will be sponsored by the Nuclear Power Group, Inc., and will be financed completely with private funds.

The dual-cycle boiling reactor is a type expected to achieve competitive generating costs with ordinary steam power plants in succeeding models, according to Mr. Francis K. McCune, Vice President of General Electric and manager of its Atomic Products Division, who announced its proposed use.

He said that the original concept of the direct boiling reactor, pioneered at the Atomic Energy Commission's Argonne National Laboratory by D. W. H. Zinn and associates, was adapted by General Electric for use in a large power station. In doing so, G-E engineers found ways to multiply the output of such reactors, permitting their application to large power plants on a commercial scale. Thus, much of the simplicity and thermal efficiency of the boiling reactors has been retained, while the power for a given size has been boosted materially.

Stability with relation to load has also been vastly improved. When increased load demands are made on the direct boiling reactor, output tends to be reduced. G-E engineers introduced a "flash tank" system into the new reactor which controls steam formation by feeding cooler water into the entrance of the reactor as load demands increase. This maintains the delicate balance of the chain reaction in such a way that the reactor automatically delivers more power to supply the load increase. The dual-cycle reactor in effect, Mr. McCune said, accommodates itself to the demands of the power system without requiring changes in reactor controls.

Steam will be provided to the turbine at two pressures. He gave as an example, 600 psi. from the reactor vessel for the first turbine stages and 350 pounds from the "flash tanks" for intermediate stages. In contrast, he said, non-boiling reactors cooled by high-temperature, high-pressure water would have to operate under a pressure of around 2,000 pounds in order to generate steam at 500 pounds for the turbine.

The dual-cycle reactor also retains the advantage of an exceptionally high degree of inherent safety due to boiling in the reactor.

UNCLASSIFIED PHYSICAL RESEARCH CONTRACTS

Award of 33 unclassified physical research contracts with universities and private research institutions was announced in May by the U. S. Atomic Energy Commission. Five are new contracts, and the remainder are renewals of contracts which have been in force. They are in addition to the 49 awarded last December and January. See this JOURNAL, Vol. 259, p. 242).

Most of the contracts are for a term of one year. One-third of them are for amounts between $1,500 and $10,000; one-third between $10,000 and $19,000, and one-third for amounts up to $97,000. One of the contracts is with the Bartol Research Foundation of The Franklin Institute.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS

A ROTATING READING HEAD FOR MAGNETIC TAPE AND WIRE

A reading head that makes possible the close examination of a short section of magnetic tape or wire is now being used at the National Bureau of Standards to locate and investigate faults in magnetic recording media. Developed by J. R. Sorrells of the NBS data processing systems laboratory, this instrument makes use of a reading head mounted on a rapidly rotating drum so that the head is in contact with the tape for a part of each revolution. Since the tape is held stationary, the head reads exactly the same set of signals once each revolution, and the playback can be displayed continuously on an oscilloscope and observed as long as desired.

In addition to providing a means for closely examining the playback signals from a specific portion of the tape, the reader can be used to scan through and edit a complete tape. The observer can easily locate any defective signals along the entire length of the recorded tape. Interchangeable parts provide a means for examining several different sizes of magnetic tape or wire.

In the design and development of magnetic tape and wire equipment for external pulse storage in electronic digital computer systems, one of the primary considerations has been reliability of operation. An important factor in magnetic storage is the condition of the tape surface itself. Errors in operation can be caused by any of several types of tape faults such as "holes" and raised spots in the magnetic surface, or creases in the tape. Very often the loss of several pulses or the gain of a single pulse may be caused by a flaw that is too small to be visible to the unaided eye. Conventional means of tape reading are not suitable for locating errors, since in the usual tape transport mechanism the tape is moved continuously past a stationary head. In investigating tape for faults it is desirable to read a small specific portion of the tape over and over again at a rapid rate, and to display on an oscilloscope a steady, clear picture of the playback signals. The rotating head reading device developed at NBS provides such a repetitive method for examining tape. Once faults are located, they can be removed or else avoided in the future, thus increasing the reliability of the tape.

For convenience, the tape reader is mounted on a vertical panel. Near the two upper corners are the shafts on which the tape reels are mounted. Although tape must be reeled manually on the NBS model, a motor drive or stepping mechanism could easily be attached. The idler shafts are friction loaded to maintain the proper tension on the tape for reading as the tape is reeled along.

At the lower center of the panel is the rotating drum on which the reading head is mounted. The drum is $2\frac{1}{8}$ in. in diameter and rotates at 10 rps.; thus the equivalent tape speed is 90 in./sec. The drum is made in two sections. The reading head is mounted on one section and has a groove or track machined around the periphery in which the tape or wire rides. This section is easily removed, and other similar sections may be substituted for different sizes of tape or wire.

The section of the drum nearest the panel is fastened to the drive shaft and is not ordinarily removed. This section is cup-shaped with the open side toward the panel. A photoelectric cell is mounted on the panel, inside the cup-shaped section, close to the periphery of the drum. A small aperture in the drum wall makes it possible to focus an externally mounted lamp on the photocell when the drum is in the proper position.

Each time the hole in the drum wall passes the light source, the light strikes the photocell and causes a small output pulse from the cell. The pulse is applied to a cathode follower which in turn triggers the oscilloscope sweep. The aperture in the drum wall is so located that the trigger pulse occurs just before the reading head makes contact with the tape, so that the oscilloscope sweep always begins slightly before the first pulse is sensed by the head. It is this timing system that provides a steady picture of the repeated playback signals on the oscilloscope screen.

Since the reading head is mounted on a revolving drum, electrical connections must be made through slip rings and brushes. A specialized slip ring assembly using commercial brushes was designed and constructed for this purpose. The three rings are made of electrodeposited silver on a premachined bakelite cylinder; the silver is further machined for good contact surfaces. The cylinder is mounted between the drum and the driving motor, and a two-wire shielded cable runs from the slip rings through the shaft to the reading head.

On the front of the panel are four grooved studs that guide the tape as it enters and leaves the reels and the rotating drum. Rubber shoes pressing firmly against the studs prevent the tape from creeping while being scanned. Interchangeable studs are provided for different sizes of tape and wire.

Trials of the equipment in the laboratory prove its usefulness in locating tape flaws and in reading recorded pulses. The playback signal on the oscilloscope screen shifts such a small amount that photographs taken with an exposure time of 15 sec. reveal no evidence of blurring. Moreover, there is no noticeable noise from the slip ring and brush assembly.

By expanding the oscilloscope sweep, it is possible to read a computer word simply by recognizing the value of each recorded digital pulse. The rotating head has been used in this way to compare information on

a magnetic wire with the paper tape from which it was recorded. This method is used to determine whether the transcribing equipment is causing trouble or the wire is at fault.

In addition to being an effective and useful means of investigating magnetic recording phenomena, the rotating-head type of the reader could also be used as a means for transcribing information directly from the keyboard to the magnetic tape. It would be most convenient to use a multichannel tape together with some provision for advancing it in short, precise steps. Each time a key on the keyboard is pressed, the corresponding character in coded form is set up in an electronic register. Then at a specific point of the rotating drum revolution, the contents are recorded on the tape in parallel form. On the next revolution of the drum, the character just recorded is compared with the character stored in the register. If the two agree, the tape advances a small distance, and the next key can be depressed to begin the next record-read-check cycle. If the two characters do not agree, the tape advance mechanism is locket out, an error indicator flashes, and the operator can either try to record again or find where the difficulty is. In this way, an operator could transcribe his problem directly from his manuscript to a magnetic tape, which then could be read directly into the computer.

THE FRANKLIN INSTITUTE

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor. 333 items have been added this month.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A.M. until 5 P.M. on Mondays, Tuesdays, Thursdays, and Fridays; 2 P. M. until 10 P. M. on Wednesdays; and 9 A. M. until 12:00 NOON on Saturdays.

RECENT ADDITIONS

AERONAUTICS

DUHEM, JULES. Histoire des Idées Aéronautiques Avant Montgolfier. 1943.
DUHEM, JULES. Musée Aeronautique Avant Montgolfier. 1943.

ASTRONOMY

CITTERT, P. H. VAN. Astrolabes. 1954.
NORTON, ARTHUR P. Star Atlas and Reference Handbook. Ed. 12. 1954.

BIBLIOGRAPHY

DUVEEN, DENIS I. AND KLICKSTEIN, HERBERT S. A Bibliography of the Works of Antoine Laurent Lavoisier 1743–1795. 1954.
SANDOVAL, FERANDO B. Bibliografía General del Azúcar. 1954.

BIOGRAPHY

DAIMLER-BENZ AKTIENGESELLSCHAFT. Karl Benz and sein Lebenswerk. 1953.

BIOLOGICAL CHEMISTRY

KENT, P. W. AND WHITEHOUSE, M. W. Biochemistry of the Aminosugars. 1955.
MCELROY, WILLIAM D. AND GLASS, BENTLEY H., ED. A Symposium on Amino Acid Metabolism. 1955.

CHEMISTRY AND CHEMICAL TECHNOLOGY

BESSKOW, S. D. Technisch-Chemische Berechnungen. Ed. 2. 1953.
BREUSCH, F. LUDWIG. Lehrbuch der Gesamten Chemie. Ed. 2. 1954.
KASSATKIN, A. G. Chemische Verfahrenstechnik. 2 vol. 1953–1954.
LEHMANN, GUNTHER. Die Wasserstoffionenmessung. Ed. 4. 1954.
LUBS, H. A., ED. The Chemistry of Synthetic Dyes and Pigments. 1955.
MALJAROW, K. L. Qualitative Anorganische Mikroanalyse. Ed. 2. 1954.
SCHELLER, HEINRICH. Einführung in die Angewandte Spektrochemische Analyse. 1953.

CIVIL ENGINEERING

MARÉ, ERIC DE. The Bridges of Britain. 1954.

ELECTRICITY AND ELECTRICAL ENGINEERING

ANDÉ, FRITZ. Betrieb und Anwendung von Leistungs- und Regelstransformatoren. 1954.
BERTELE, HANS VON. Niederdruck-Stromrichterventile. 1952.

BLASCHKE, HEINRICH. Schaltung und Bemessung von Sammelschienen Elektrischer Anlagen. Ed. 2. 1949.
BUCHHOLD, THEODOR. Elektrische Kraftwerke und Netze. Ed. 2. 1952.
PFLIER, PAUL MARTIN. Elektrizitätszähler. 1954.
POWEL, CHARLES A. Principles of Electric Utility Engineering. 1955.
RYDER, JOHN D. Networks, Lines, and Fields. Ed. 2. 1955.

ENGINEERING

BATHE, GREVILLE. An Engineer's Notebook. 1955.
POETTER, HEINRICH. Die Werkstoffprüfung im Maschinenbau und in der Elektrotechnik. Ed. 2. 1952.

GEOLOGY

SAUKOW, A. A. Geochemie. 1953.

HOROLOGY

BAILLIE, G. H. Clocks and Watches; an Historical Bibliography. 1951.

MANUFACTURE

EDWARDS, JUNIUS DAVID AND WRAY, ROBERT I. Aluminum Paint and Powder. Ed. 3. 1955.
MÖLLERING, IRIS AND MÖLLERING, HEINRICH. Verfahren der Gerbereichemie. 1954.

MATHEMATICS

ARCHIBALD, RAYMOND CLARE. Euclid's Book on Divisions of Figures. 1915.
BAKER, HENRY FREDERICK. An Introduction to the Theory of Multiply Periodic Functions. 1907.
BLOCH, S. SCH. Angenäherte Synthese von Mechanismen. 1951.
BOHR, HARALD. Collected Mathematical Works. 1952.
BOOTH, ANDREW D. Numerical Methods. 1955.
CHUNG, J. H. AND DELURY, D. B. Confidence Limits for the Hypergeometric Distribution. 1950.
COOKE, RICHARD G. Infinite Matrices and Sequences Spaces. 1950.
KARLSON, PAUL. Vom Zauber der Zahlen. 1955.
MIDDLEMISS, ROSS R. Analytic Geometry. Ed. 2. 1955.

MECHANICAL ENGINEERING

KASCHIRIN, A. I. Technologie des Machinenbaus. 1953.
SODANO, EUGENE. Pour le Tourneur-Mécanicien. Ed. 2. 1954.
U. S. NATIONAL CONGRESS OF APPLIED MECHANICS. Proceedings. 2nd. 1954.

METALLURGY

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS. Transactions. Vol. 199–201. 1955.
BALSCHIN, M. JU. Pulvermetallurgie. 1954.
JASBOGORODSKI, I. S. Elektrolytisches Härten; Erhitzen von Metallen und Legierungen in Elektrolyten. 1951.
ROTHERY, WILLIAM HUME. Electrons, Atoms, Metals and Alloys. 1955.
SIMMONS, WARD F. AND CROSS, HOWARD C. Report on the Elevated-Temperature Properties of Selected Super-Strength Alloys. 1954.

MINING ENGINEERING

TERPIGOREW, A. M.; DEMIDOW, P. N. AND PROTODJAKONOW, M. M. Bergbaumaschinen für die Gewinnung von Flözlagerstätten. 1953.

OPTICS

HAAS, HANS. Polarisationsoptik. 1953.
LÖWE, CARL FRIEDRICH. Interferenz-Messgeräte und Verfahren. 1954.
MAKSUTOW, D. D. Technologie der Astronomischen Optik. 1954.

PETROLEUM TECHNOLOGY

The Chemistry of Petroleum Hydrocarbons. Vol. 2–3. 1955.

PHYSICS

DUGAS, RENÉ. La mechanique au xvii^{e} siècle. 1954.
FINCK, JOSEPH LOUIS. Thermodynamics from the Classic and Generalized Standpoints. 1955.
HARRIS, NORMAN C. AND HEMMERLING, EDWIN M. Introductory Applied Physics. 1955.
HEISENBERG, WERNER. La Physique du Noyau Atomique. 1954.
JEANS, SIR JAMES HOPWOOD. The Dynamical Theory of Gases. Ed. 4. 1954.
KRAUS, ROBERT. Technische Mechanik. 2 vol. 1953–1954.
MANEGOLD, ERICH. Kapillarsysteme. Vol. 1. 1955.
MAYER, MARIA GOEPPERT AND JENSEN, J. HANS D. Elementary Theory of Nuclear Shell Structure. 1955.
MENZEL, DONALD H., ED. Fundamental Formulas of Physics. 1955.
ROSSINI, FREDERICK DOMINIC, ED. Thermodynamics and Physics of Matter. 1955.
ROUTH, EDWARD JOHN. The Advanced Part of a Treatise on the Dynamics of a System of Rigid Bodies. Ed. 6. 1955.
SCHNEIDER, P. J. Conduction Heat Transfer. 1955.
SHORTLEY, GEORGE AND WILLIAMS, DUDLEY. Elements of Physics. Ed. 2. 1955.
SIEGBAHN, KAI, ED. Beta- and Gamma-ray Spectroscopy. 1955.
SZABÓ, ISTVAN. Einfürung in die Technische Mechanik. 1954.

PLASTICS

RILEY, MALCOLM W., ED. Plastics Tooling. 1955.

SCIENCE

ADAMS, JOHN COUCH. The Scientific Papers of John Couch Adams. 2 vols. 1896.
BECK, L. J. The Method of Descartes. 1952.
HESSE, MARY B. Science and the Human Imagination. 1955.
LENOBLE, ROBERT. Mersenne ou la Naissance du Mécanisme. 1943.
NATIONAL RESEARCH COUNCIL. Review 1954. 1954.
NEEDHAM, JOSEPH. Science and Civilization in China. Vol. 1. 1954.

SUGAR

AMERICAN SOCIETY OF SUGAR BEET TECHNOLOGISTS. Proceedings. 8th. 1955.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

KROLL, W. J.: How Commercial Titanium and Zirconium Were Born
MOON, PARRY AND DOMINA EBERLE SPENCER: On Electromagnetic Induction
HONNELL, PIERRE M. AND ROBERT E. HORN: Matrices in Analogue Mathematical Machines
SALZER, HERBERT E.: Complex Zeros of the Error Function
MEES, C. E. KENNETH: The Structure of the Developed Photographic Image
ADLER, F. P.: Minimum Energy Cost of an Observation
YU, YI-YUAN: On the Complex Representation of the General Extensional and Flexural Problems of Thin Plates and their Analogies
MOON, PARRY AND DOMINA EBERLE SPENCER: On the Ampere Force

NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

NICOL H. SMITH, DIRECTOR

CHEMICAL REACTIONS OF AIR POLLUTANTS *

BY

PHILIP L. HANST, EDGAR R. STEPHENS AND WILLIAM E. SCOTT

Periods of temperature inversion in Los Angeles are frequently accompanied by severe smog attacks. Smog usually increases during the morning hours to a peak around noon and then decreases; this indicates that sunlight plays an important role in the development of smog. It suggests that photochemical reactions among pollutants in the air are of major importance. Concentration of oxidant (probably ozone) in the atmosphere is also known to be closely related to smog severity.

Under the sponsorship of the American Petroleum Institute the Chemical Kinetics and Spectroscopy Section of The Franklin Institute Laboratories is studying the reaction of various hydrocarbons with ozone and with nitrogen dioxide in artificial sunlight and air. Experiments have been performed with reactants at partial pressures of the order of 1 mm. of mercury. A carbon arc served as a source of ultraviolet radiation. After passage through a Pyrex flask, which absorbs wave lengths shorter than 3000Å, this radiation approximates sunlight both in intensity and spectral distribution in the ultraviolet region. Infrared absorption was used to analyze the products of reaction.

Representatives of four types of hydrocarbons have been studied: 1-olefins, straight-chain saturates, branched-chain saturates, and saturated cyclics. Emphasis was placed on the study of 1-pentene. The saturated hydrocarbons proved to be much less reactive than the 1-olefins.

At the pressures used in these experiments, ozone and 1-pentene react very rapidly to produce gaseous products and a liquid mist. There is evidence of the transitory formation of an ozonide. Butyraldehyde, carbon dioxide, and carbon monoxide—but not formaldehyde—are identified in the gaseous products. With excess ozone some of the butyraldehyde is oxidized to peroxy acid. Reactions of ozone with a series

* This is an abstract of a paper entitled "Reactions Involving Ozone, Nitrogen Dioxide, and Organic Compounds at Low Concentrations in Air," presented to a Session on Smoke and Fumes, 20th Midyear Meeting of the American Petroleum Institute's Division of Refining, in St. Louis, May 10, 1955. The paper will be published in full in the *Proceedings* of the Division of Refining of the American Petroleum Institute.

of straight-chain aldehydes showed that the three-and four-carbon aldehydes produced the most peroxy acid.

The photochemical reaction of ozone with 2-methylpentane produced an unidentified carbonyl compound, carbon dioxide, and acetone. *n*-hexane and cyclohexane were both less reactive with ozone than 2-methylpentane.

Under "sunlight," 1-pentene reacts with nitrogen dioxide in air to produce aldehyde, carbon dioxide, propyl nitrite, propyl nitrate, and peroxy acid. The nitrite and nitrate are not formed when this reaction takes place in nitrogen rather than air. Propyl nitrate is also produced when butyraldehyde reacts with nitrogen dioxide under "sunlight" in air, but not if pure nitrogen is substituted for the air. In contrast, the reaction between peroxy butyric acid and nitrogen dioxide produces the nitrate and nitrite even without molecular oxygen. We conclude that

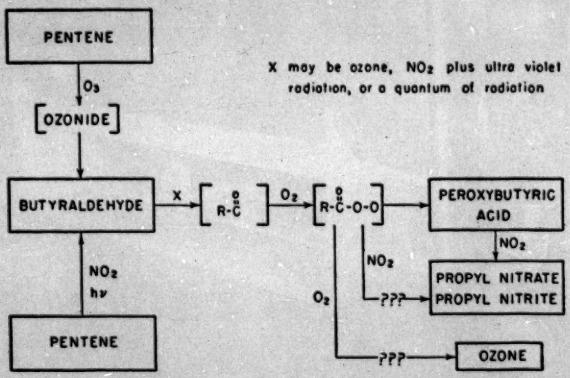

FIG. 1. Schematic summary of findings for 1-pentene.

in the 1-pentene-nitrogen dioxide reaction, alkyl nitrite and alkyl nitrate are produced by the reaction of nitrogen dioxide with the peroxy butyric acid first produced.

The photochemical reaction of nitrogen dioxide with 2-methylpentane produces alkyl nitrate, alkyl nitrite, carbon dioxide, acetone, and probably another carbonyl compound. Molecular oxygen is necessary for the formation of the nitrite and nitrate. Nitrogen dioxide reacts more rapidly with 2-methylpentane than with *n*-hexane or cyclohexane.

Figure 1 is a summary of the experimental findings on the reaction of the sample olefin (1-pentene) with ozone or nitrogen dioxide in air under "sunlight." Saturated hydrocarbons presumably are converted to nitrate and nitrite in an analogous series of reactions.

All of the work described above was done with reactants at partial pressures of about 1 mm. Hg. These are, of course, far higher than are ever encountered in any polluted outdoor atmosphere. To extend the studies to lower, more representative concentrations, we built a long-path infrared absorption cell that embodies the multiple reflection system devised by White. With a base path-length of 3 meters any integral multiple of four passes (12 meters) can be obtained, up to the limit imposed by energy losses.

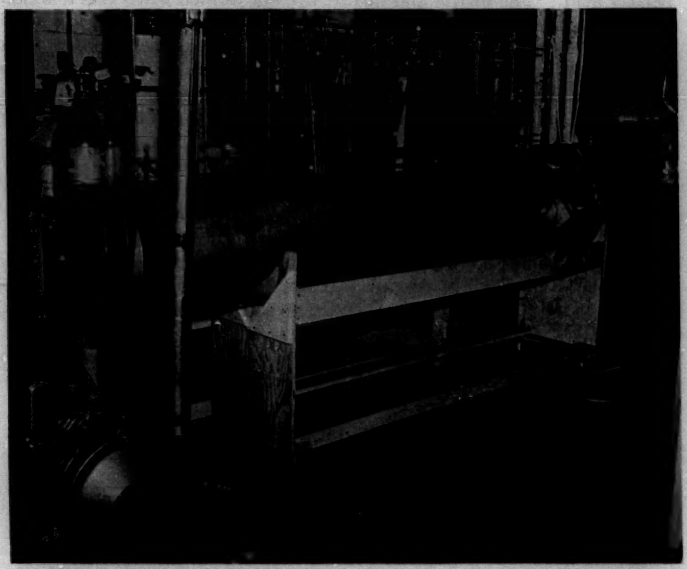

FIG. 2. Long-path absorption cell for infrared analysis of mixtures of air pollutants. Square window at right admits carbon-arc "sunlight."

At present the cell (Fig. 2) is being used at path-lengths of about 500 meters. With this path-length it is possible to detect products in concentration of a few tenths of a part per million, which is close to actual atmospheric concentrations.

This fundamental work on the reactions of hydrocarbons, at low concentrations, with other constituents of the atmosphere should shed much light on the mechanism of atmospheric reactions and their products.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, M.D., FOUNDER WILLIAM G. BATT, D.Sc., DIRECTOR

THE EFFECTS OF CERTAIN SUBSTITUTED PYRIDINES ON THE GROWTH OF *LACTOBACILLUS CASEI*

BY

SAMUEL J. de COURCY, Jr. AND FRANCIS E. REINHART

As part of a proposed research program concerned with the biological screening of various organic compounds and directed primarily toward a search for anti-tumor agents, an investigation of the possible effects of a series of substituted pyridines on the growth of *Lactobacillus casei* has been initiated. Although the first phase of this work is mainly concerned with a search for compounds which possess general inhibitory properties, use has been made of several well-defined growth media devised by Hitchings *et al* (1) for the study of antagonistic as well as simulatory activities with respect to the folic acid, thymine, and purine requirements of this organism. These authors have emphasized the possible relationships which such activities may bear to the biosynthesis of nucleic acids.

The observations which form the basis of this report demonstrate an appreciable inhibitory activity toward *L. casei* for several of the compounds studied. Little if any indication of a relationship between this activity and the nutrilites discussed above was noted.

Except for several modifications, the experimental procedure was that described by Hitchings *et al* (1). The composition of the basal medium (O) was modified by the use of Vitamin-Free Enzymatic Casein Hydrolysate (Nutritional Biochemicals Corp.) at a concentration corresponding to 5 g. solid per liter. Supplementation of this medium with adenine sulfate (10 mg. per l.), thymine (1 mg. per l.), or folic acid (0.05 μg. per l.) gave media (P), (OT), and (OFA), respectively. Addition of thymine (1 mg. per l.) to (P) and of adenine sulfate (10 mg. per l.) to (OFA) resulted in the media (PT) and (PFA), respectively.

The extent of growth of *L. casei*, ATCC 9595, was determined by averaging duplicate alkali (N/10 NaOH) titration values for the lactic acid formed in 10 ml. of medium after 41-hr. growth at 37° C. Average control growth values in terms of N/10 lactic acid produced per 10 ml. medium for the media (O), (OT), (P), (OFA), (PT), and (PFA) were 0.4, 0.5, 0.8, 3.9, 3.1, and 7.2 ml., respectively.

Each compound listed in Table I was tested in each of the six media at a concentration of 100 μg. per ml. In addition, I, II, and III were tested at 10 μg. and 1 μg. per ml.

Under the conditions of the experiments, none of the compounds tested was found to stimulate growth of *L. casei* in the media (O), (OT), or (P). With respect to inhibitory activity in media (OFA), (PT), and (PFA) it is seen (Table I) that compounds I, II, III, and IV are the most active. Possible reversal of activity by adenine, which would be indicated by a relatively low degree of inhibition in (PFA) as compared with that in (OFA), is not evident, except perhaps to some degree with compound II at 10 μg. per ml. Nor is appreciable folic acid antagonism indicated, as would be the case if extensive inhibition in (OFA) and (PFA) were associated with low inhibition in (PT).

TABLE I.—*Inhibition of Growth of Lactobacillus casei.*

No.	Compound	Method of Synthesis Reference	Concn. μg./ml.	Medium OFA	PT	PFA
				Per cent Inhibition		
I	5-Nitro-2-pyridinethiol	(7)	100	90	92	98
			10	90	98	74
			1	30	12	11
II	S-(5-Nitro-2-pyridyl)-thiuronium chloride	(8)	100	94	91	97
			10	72	85	30
			1	*25**	10	0
III	5-Nitro-2-(phenylsulfonyl)-pyridine	(9)	100	92	93	95
			10	20	45	11
			1	0	22	0
IV	5-Nitro-2,3′-sulfonyldipyridine	**	100	82	82	96
V	5-Amino-2,3′-sulfonyldipyridine	**	100	14	11	0
VI	*o*-(5-Nitro-2-pyridylsulfonyl)-benzoic acid	(3)	100	0	44	0
VII	*o*-(5-Nitro-2-pyridylmercapto)-benzoic acid	(3)	100	*24**	*20**	*17**
VIII	6-(*p*-Nitrophenylmercapto)-nicotinic acid	(4)	100	25	20	14
IX	*N*-(3-Pyridyl)-3-pyridine-sulfonamide	(5)	100	0	0	0
X	1-(3-Pyridylsulfonyl)piperidine	**	100	0	0	0
XI	4-(3-Pyridylsulfonyl)morpholine	**	100	0	0	0

* Per cent stimulation
** Unpublished data

The inhibition shown by compound III (at 1 μg./ml.) and by compound VI in medium (PT), where growth occurs in the absence of folic acid, could indicate interference with the utilization of adenine or thymine. This will be investigated further, as will be the growth stimulation apparently elicited by compounds II and VII.

Of the four most active compounds in this series, 5-nitro-2-pyridinethiol has previously been reported to be highly active against *Mycobacterium tuberculosis* (2), while previous reports from this Laboratory indicate that compound III prevents the growth of *Staphylococcus*

aureus in broth culture at a concentration of 120 μg. per ml. (3). Several tests made in this Laboratory have also shown that growth of the latter organism in heart infusion broth can also be prevented by 60 μg. per ml. of compound IV, but addition of the compound to this medium previous to autoclaving destroys its activity. Inhibitory activity toward *Staphylococcus aureus* growing in chemically-defined medium has also been observed for compound VII (3) and compound VIII (4).

With respect to the activity of compound II, it was noted that solution in water at pH 7 brings about a partial conversion to the active thiol (compound I). Hence, this ease of conversion is probably responsible for its activity. Closely related 2-pyridine-thiols substituted in the 5-position as well as several of the corresponding thiuronium compounds have been reported to possess appreciable inhibitory activity toward a number of bacterial species (6).

A continuation of the screening program described in this report is in progress. Special emphasis is being placed on reversal studies in an effort to elucidate the mechanism of action of compounds found to show inhibitory activity toward the growth of *L. casei*.

REFERENCES

(1) G. H. HITCHINGS, G. B. ELION, E. A. FALCO, P. B. RUSSELL, M. B. SHERWOOD AND H. VANDERWERFF, *J. Biol. Chem.*, **183**, 1 (1950).
(2) Y. YAMAMOTO AND H. ŌYA, *J. Pharm. Soc. Japan*, **72**, 1022 (1952); *Chem. Abstr.*, **46**, 10286f (1952).
(3) F. E. REINHART, JOUR. FRANKLIN INST., **249**, 248 (1950).
(4) F. E. REINHART, *ibid.*, **249**, 427 (1950).
(5) F. E. REINHART, *ibid.*, **236**, 316 (1943).
(6) H. S. FORREST AND J. WALKER, *J. Chem. Soc.*, **1948**, 1939.
(7) W. T. CALDWELL AND E. C. KORNFELD, *J. Am. Chem. Soc.*, **64**, 1695 (1942).
(8) A. R. SURREY AND H. G. LINDWALL, *ibid.*, **62**, 1697 (1940).
(9) H. C. WINTER AND F. E. REINHART, *ibid.*, **62**, 3508 (1940).

QUANTUM MECHANICS, by F. Mandl. 233 pages, diagrams, 16 × 25 cm. New York, Academic Press, Inc., 1954. Price, $5.80.

This book originated from a series of lectures given by the author at A.E.R.E., Harwell. After an excellent mathematical introduction, covering vector analysis with mathematical generalizations common to classical mechanics, such as normal coordinates and eigenfunctions, the author proceeds in Chapter II with the Schrödinger wave equation. The build-up of this equation and its interpretation are covered with clarity. The energy eigenfunctions are discussed and presented in vector notation. Chapter III discusses the linear harmonic oscillator and one-dimensional potential barriers, followed by angular momentum and spin theory. Chapter IV includes a resumé of the Hamiltonian classical mechanics, with concepts leading to its interpretation in quantum mechanics, along with a discussion of operators. Leading to the Uncertainty Principle, the author includes the measurements of observables.

Chapters V and VI cover a careful presentation of matrix operators, including the angular momentum vector, the Pauli spin matrices, and the compounding of angular momentum. This is followed by a more detailed discussion of the Pauli principle. The closing chapters, VII, VIII, and IX, cover a general discussion of perturbation theory, collision processes and group theory. An appendix on vectors, and hints for the solution of exercises in the text are also included.

The wave-mechanical concepts as governed by quantum energy levels and the statistical interpretation of the corresponding eigenfunctions, may be assumed as fundamental postulates, wherein the Newtonian classical mechanics is a special case. However, if we reverse the order wherein classical mechanics may offer a more physical feel of energy, momentum and other physical concepts, and the build-up of generalizations in the form of Lagrangian and Hamiltonian functions, followed by normal coordinates and modes of vibration interpreted from the classical aspect, a transition to or a coordination with quantum mechanics is most desirable. The Hamiltonian, with momentum as a coordinate, and the mathematical background of wave theory and normal modes and their orthogonal relations, provides a physical acquired feel to be extended with a new interpretation and restriction to Quantum.

The author has accomplished this transition in an admirable way. Another feature of this book lies in the clarity in the discussion of mathematical operating methods and the physical interpretation of the Schrödinger wave equation and its applications.

RUPEN EKSERGIAN

RADIATION BIOLOGY: ULTRAVIOLET AND RELATED RADIATIONS (VOL. II), edited by Alexander Hollaender. 593 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $8.00.

The present volume is the second in this excellent and authoritative series upon radiation biology. Volume I, subtitled "High Energy Radiations," appeared last year (see review, J. F. I., Vol. 258, pp. 321–323). The last of the series, Volume III, is subtitled "Visible Light" and is in preparation. Dr. Hollaender prepared Volume II with the cooperation of collaborating editors Drs. F. Daniels, A. W. Pollister, J. R. Loofbourow and L. J. Stadler. The book is dedicated to the memory of two of the editorial associates, namely Drs. Loofbourow and Stadler.

Although this volume covers the field of ultraviolet radiation, it also contains a large amount of material on high-energy radiation. It is important therefore to quote the editor as follows, "Since both parts of the spectrum induce similar biological effects, no clear line can be drawn between the two. Microbiology, for example, is discussed in both volumes but occupies a more prominent place in the second. Actually,

Volumes I and II compose a unit and should be read as such."

The volume, which consists of 14 chapters written by 17 specialists, opens with an account by R. Livingston upon photochemical reactions which are conveniently divided into the steps that constitute the "mechanism of the reaction." In what is likely to be an extensively referred to chapter, L. J. Buttolph has described the practical applications and sources of ultraviolet energy. Treated with excellent figures are germicidal-action curves, susceptibility to ultraviolet (injury, mutation and killing exposures), sources of ultraviolet, ultraviolet disinfection, protection and processing of products with ultraviolet. The next chapter by J. A. Sanderson and E. O. Hulburt presents sunlight as a source of radiation. This is followed by an account of the technique of study of biological effects of ultraviolet radiation by J. F. Scott and R. L. Sinsheimer. The remaining chapter headings, with authors, will suggest the broad scope of this reference work: "Ultraviolet Absorption Spectra" (R. L. Sinsheimer); "A Critique of Cytochemical Methods" (A. W. Pollister); "The Effect of Ultraviolet Radiation on the Genes and Chromosomes of Higher Organisms" (C. P. Swanson and L. J. Stadler); "The Effects of Radiation on Protozoa and the Eggs of Invertebrates Other than Insects" (R. F. Kimball); "Radiation and Viruses" (S. E. Luria); "Effects of Radiation on Bacteria" (M. R. Zelle and A. Hollaender); "Radiation Studies on Fungi" (S. Pomper and K. C. Atwood); "Photoreactivation" (R. Dulbecco); "Sunburn" and the concluding chapter, "Ultraviolet Radiation and Cancer," (both by H. F. Blum).

The chapter on the discussion of cytochemical methods by Pollister will prove to be invaluable to those investigators seeking quantitative cytological data on cell constituents. Not too long ago cytologists spoke of intensity of a stain or color reaction as weak, strong, or very dark. The newer devices and techniques are described which permit actual measurement and computation in the photometric analysis of cell parts.

Kimball has elected to review the effects of radiation on both Protozoa and the eggs of invertebrates (other than insects) because the single cells are to be found in a liquid medium and "the methods employed have tended to emphasize the cell as an individual rather than as a member of a population." He has presented a valuable four-page table which, in synoptic form gives the kind of organism, the radiation employed, the biological effect and the reference.

In his thorough discussion of radiation and viruses, Luria notes that there is a certain degree of parallelism between particle size and radiosensitivity for different viruses and for a given radiation, at least qualitatively. This reviewer notes that in his own research with eight species of a genus of ciliated Protozoa, the smallest proved easily to be the most radiosensitive and wonders whether or not a similar correlation may be found in related groups of the one-celled animals.

The chapter on sunburn by Blum is a very timely account describing the facts and fancy on the causes of sunburn and misconceptions regarding tanning. The review points to the need for continued study of these phenomena with considerations for known physical and physiological aspects of the problem. We have an explanation why one is not likely to be sunburned before 8 A.M. or after 4 P.M. even on a bright midsummer day even though the sun may be shining brightly.

It may come as a surprise to some to learn that the erythemal radiation (reddening of the skin) may be more intense early in May than it is at the end of August; that at the time of the summer solstice there is about the same sunlight in Seattle, Washington, as in the tropics and with other things being equal, the same chance for equality in sunburning. There is an explanation why one may sit under a beach umbrella and protected from the direct sunradiation but still receive a severe sunburn from sky radiation which is not cut off by the umbrella. These and many other features regarding sunburn and suntan are set forth in an interesting manner.

In the last chapter of the book dealing with ultraviolet radiation and cancer, Blum has examined both qualitatively and quantitatively the hypotheses of carcinogenesis including the somatic mutation theory of can-

cer and the separate induction and growth periods in which a tumor is said to grow "autonomously." He then describes his theory suggesting a framework with which the mechanism for carcinogenesis needs to be fitted.

Most ardent sun-bathers may be shocked to read that based upon existing data ". . . it seems difficult to reach any conclusion other than that ultraviolet radiation of sunlight is a major causal factor in cancer of the skin in the white population of the United States."

Like the preceding volume, each chapter is prefaced by a synoptic outline of the contents and each chapter is concluded with an adequate bibliography. An extensive name and subject index adds to the greater usefulness of this excellent volume.

RALPH WICHTERMAN

INTEGERS AND THEORY OF NUMBERS, by Abraham A. Fraenkel. 102 pages, 18 × 26 cm. New York, Scripta Mathematica, 1955. Price, $2.75.

This book is a slightly expanded translation of the first part of the author's Hebrew book *Mavo Le Mathematika* (Introduction to Mathematics) which may not be as well known as his *Abstract Set Theory*. The present volume, as the first in the series, presents the elementary theory of numbers. It is geared to the requirements of an adult education program given by the author in Palestine since 1929. Accordingly, his treatment of the subject aims to arouse the interest of gifted high school students, curious laymen, or college freshmen, basically interested in the fundamentals of mathematics.

Ever since man has learned to count he has been prepossessed with a strange fascination for his own, abstract creation, called number. The first chapter, Natural Numbers as Cardinals, reviews the history, concept and ordering of cardinals from a set-theoretical viewpoint. The next chapter, Natural Numbers as Ordinals, creates in the reader's mind the awareness of the need for ordinal numbers. Peano's Axioms are analyzed and the independence of the axioms for ordinals is demonstrated. The arithmetic of ordinals is developed and leads, of course, to the desired relationship between ordinals and cardinals. The author turns now to the Theory of Numbers. His choice for the first topic is a natural: Prime Numbers and Their Distribution. Theorems requiring only elementary tools are proved and much small talk provides the reader with information concerning recently discovered "large" primes ($2^{2^{127}}-1$), prime twins, Goldbach's Theorem, Gauss' discovery about the partition of a circle into $p = 2^n + 1$ equal parts, Fermat's theorems, congruences, perfect, amicable, algebraic, and ideal numbers, etc.

Chapter IV treats the Rational Numbers as extension of the number-concept of natural numbers by applying Hankel's Principle of the Permanence of Formal Laws which requires the formal laws in the extended domain to be the same, as much as possible, as those of the original domain. The extension is continued by introduction of negative integers, and fractions, until there emerges the concept of the field of rational numbers for which the necessary operations are formulated, using first number pairs, then the customary single symbols. Several proofs and remarks of a more complicated nature, although not above the level maintained by the author throughout the book, are collected in an Appendix.

The author has been accused of prolixity, but the layman will appreciate the superb way in which Professor Fraenkel drives home a point and makes it stick. His aim is completeness, to be accomplished with simple tools. He cites numerous philosophical interpretations and any number of relevant references for readers who wish to get a glimpse of advanced aspects of number theory. The expository treatment and the absence of problems seem to blend nicely; although this mixture may not be the best class room text, it makes fascinating reading for those "interested in knowing what mathematics really deals with."

CARL HAMMER

ELEMENTARY THEORY OF NUCLEAR SHELL STRUCTURE, by Maria Goeppert Mayer and J. Hans D. Jensen. 269 pages, diagrams, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1955. Price, $7.75.

This book presents an extremely interesting and clearly written discussion of the shell model of the nucleus. The empirical

approach to the problem of the nucleus is followed, and the results of many experiments are reviewed in the light of the "single particle" model. It is shown how great quantities of experimental data have been analyzed and given a meaningful interpretation with the aid of the relatively simple shell theory. Practically all phases of nuclear physics from nuclear magnetic moments to such more recently emphasized concepts as spin-orbit coupling and isobaric spin are discussed. It appears to be particularly certain that owing to its lucid style, this book can be read with nearly complete understanding by experimental physicists who have not necessarily specialized in nuclear physics.

A mathematical appendix supplies with clarity treatment of certain special topics which are needed to achieve a working knowledge of the theory of shell structure. Although the book seems not to have been necessarily intended as a text book, it could be readily employed in presenting a course on nuclear models which might be given for students commencing research problems.

It has been unusually interesting to note the appearance of this book which is based upon experimental results drawn from all parts of the periodic table of the elements. With the acceptance of shell structure and the single particle concept, many aspects of the more complex heavy nuclei have been rendered simple. C. E. MANDEVILLE

SERVOMECHANISMS AND REGULATING SYSTEM DESIGN, VOL. II, by Harold Chestnut and Robert W. Mayer. 384 pages, diagrams, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1955. Price, $8.50.

When the first volume of this text was published in 1951, it was almost immediately adopted by working engineers in the field as the authoritative text. Many schools have adopted it as the standard for graduate courses in servomechanisms and control systems. The publication of the second volume has been awaited for four years, more or less impatiently, by those who were expecting a complete and authoritative coverage of advanced topics for the working engineer. We have not been disappointed. The new volume covers such subjects as techniques of measurement of frequency response and transient characteristics, practical networks, and amplifier circuits. The latter half of the volume thoroughly covers non-linear elements, from the standpoints of producing desirable performance through non-linear characteristics and of avoiding undesirable performance because of the non-linearities. Examples in the fields of jet engine, computer and auto-pilot systems, among others, are introduced to clarify the treatment. It is this reviewer's prediction that Volume II will take its place beside Volume I as a very welcome and much needed reference and working handbook for the system designer and the student in the field of control systems. BRUCE B. YOUNG

WOOL, ITS CHEMISTRY AND PHYSICS, by Peter Alexander and Robert F. Hudson. 404 pages, diagrams, 15 × 22 cm. New York, Reinhold Publishing Corp., 1954. Price, $10.00.

The main purpose of this excellent book is unquestionably to present in comprehensive form the scientific researches in wool and proteins in general. A good beginning is made with a detailed presentation of the morphology of hair, supplemented with sound experimental data.

To the surface chemist the chapters on Surface Properties, Sorption and Swelling, and Rate Processes should be keenly interesting. Methods that have been used successfully on mineral and metal surfaces for measuring surface area have been used effectively with wool. Electrical and frictional effects are discussed as they are peculiar to wool. Experiments and methods of measurement of these effects are described and evaluated. The mechanisms of sorption and swelling are gone into in detail and presented in a very scientific and interesting fashion. Many data are presented to support some of the theories for swelling of wool. A presentation is made of the many possible mechanisms involved in the diffusion and penetration of different molecules into wool.

A chapter on the mechanical properties of wool under various conditions discusses the elasticity, plastic flow, and permanent deformation of wool fibres. Additional chapters discuss such important phases of wool technology as acid-base characteristics, chem-

ical reactivity and composition, ion exchange and dyeing equilibria. The references are copious, and the text fully supported with figures.

This is an extremely interesting and scientific presentation of the problem of wool technology. It may not be amiss to add that the information is presented clearly and is well organized. S. N. MUCHNICK

MODEL ANALYSIS OF STRUCTURES, by T. M. Charlton. 142 pages, diagrams, 15 × 22 cm. New York, John Wiley & Sons, Inc., 1954. Price, $5.00.

The potentiality of augmenting engineering problems through model analysis is intriguing. This little book is designed to cover this field in conjunction with elementary structures. The author explains the C. E. Beggs method, the "Continostat" by Gottshalk, and the Rieckhof's apparatus. The first part of the book covers the similarity and dimensional approach for models with respect to their full scale prototype, including Buckingham's π theory. A discussion of virtual work methods, as the Muller-Breslau principle, is included. Some techniques on compensating dynamometers for the measurement of forces in models, moment indicators and the compensating balance are briefly discussed.

While the book covers a general survey for model structure testing, it is believed the discussion of the techniques of model testing could be more detailed. This might include strain gages and actual design of model structures, with a comparison of testing methods. RUPEN EKSERGIAN

PROGRESS IN PHOTOGRAPHY, edited by D. A. Spencer. Volume II, 334 pages, 19 × 25 cm. London, Focal Press, Ltd.; New York, Am. Photographic Book Pub. Co.; no date.

The world-wide literature of research, technology and application in the field of photography for the period 1951–1954 is authoritatively reviewed in this volume. The sixty-three condensed accounts, appealing primarily to the specialist, were prepared by authorities in technical aspects of photography from the United States, Great Britain and Germany, supervised by a five-man editorial board. In spite of the diverse interests of the reviewers, there is practically no overlap of material, attesting to the care taken in editing this reference work. Each account closes with a list of references which allows the reader to consult original material for more detailed accounts than printed in the book.

Ten sections and an appendix discuss: photographic equipment; photographic theory of images and material; color photography; photographic processing; cinematography; special techniques; special applications; radiography and diffraction; and photographic organizations and standards.

The degree of technical detail varies somewhat from chapter to chapter. The sections on the structure of photographic images as discussed here should appeal particularly to physical chemists; the sections on light sources, to practical amateur and professional photographers; and the sections on color reproduction, sensitization methods and mechanical processing should appeal to experimentalists. The industrial and research applications presented are drawn from the fields of medicine, science, law and engineering.

The volume is recommended for serious photographers interested in the technical advances in the most recent past.

S. CHARP

ORGANIC SYNTHESES, COLLECTIVE VOLUME III, edited by E. C. Horning. 890 pages, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1955. Price, $15.00.

This, the third collective volume, covers the material presented in Annual Volumes 20 to 29, and as in the preceding collective works, all of the procedures have been rechecked, revised and brought up-to-date. In addition, seven new and checked procedures have been added, together with new safety precautions for three of the organic preparations. This volume also contains methods of preparation for the most used hydrogenation catalysts, and complete working details for a laboratory ozonizer. In all, there are over 300 carefully tested syntheses and procedures presented in this book in the same lucid and easily followed style that is typical of the series.

The reviewer finds this a very difficult book to review critically with respect to

context. It has long been recognized that *Organic Syntheses* is one of the most valuable contributions to the field of references in organic chemistry in modern times. Its procedures are clearly written, accurate, convenient, and complete in detail thus saving the synthesist many hours of literature searching and laboratory experimentation. No amount of words can describe the value of such a source of information to the laboratory worker. In Collective Volume III an added convenience has been included. It is an index divided into six parts as follows: type of reaction, type of compound, formula, solvent and reagent, illustrations, and general indices. This, of course, is again a time-saving device that has been provided for the reader's benefit.

The Organic Syntheses Series, which naturally includes Collective Volume III, has been praised by both reviewers and users. Suffice it to say that any organic chemist who is active in his field should not be, and cannot afford to be, without this latest addition to the reference literature of organic chemistry.

DONALD H. RUSSELL

SOLUBILIZATION AND RELATED PHENOMENA, by Mary Evelyn Laing McBain and Eric Hutchinson. 259 pages, diagrams, 16 × 24 cm. New York, Academic Press Inc., 1955. Price, $7.00.

"Solubilization" is the name given by J. W. McBain to a particular mode of bringing into solution substances that are otherwise insoluble in a given medium. The bases of solubilization are colloidal solutions, and these are referred to in considerable detail. The author lists several main classes of solution: true solutions, emulsions, colloidal solutions, mixed solvents, hydrotopy, specific complex formation, suspension and protective action.

"Solubilization" involves the complete disappearance of the original solid particle or liquid droplet, as it is taken up, molecule by molecule, into the organized colloidal particles of the stable colloid itself.

Although the name "solubilization" is a new one, the theory is very old—deriving its origin when soap was first made. Its phenomenon was recorded as far back as 1846.

The authors first trace the history of the subject which has been of interest in the last fifty years. This is followed by a short but very interesting chapter which illustrates solubilization as sorption phenomena and their interpretation in a simple way from the standpoint of thermodynamics.

Chapter Three forms the basic reference of the text dealing with the "Properties of Colloidal Electrolytes."

The remaining first half of the book is concerned with the data and facts of solubilization which are too numerous and diverse to speak of here. However I highly recommend it as a rather intensive review of the subject which is followed by an extensive bibliography.

The remaining chapters discuss the mechanism of solubilization; co-solvency, blending and hydrotopy; physiological aspects and practical applications.

The text is concluded with two appendices dealing with "The Theory of Light Scattering" and "The Behavior of Polysoaps."

PHYLLIS A. PARKIN

THEORETICAL PRINCIPLES OF ORGANIC CHEMISTRY, by Walter Hückel, translated from the corrected seventh German edition by F. H. Rathmann. 904 pages, 18 × 26 cm. Houston, Elsevier Publishing Company, 1955. Price, $15.00.

In the preface of this large volume, the author makes the following statement: "The guiding principle on which the structure of this work is based is the development, from the very beginning, of the theories which claim the attention of the organic chemist. Essentially we have dealt with the material in chronological order. In considering the modern development of organic chemistry, we have concerned ourselves much less with highly speculative theories than is usual in works of this type, despite the fact that these theories may be very ingenious and ultimately prove to be correct."

The theoretical principles of organic chemistry are not treated in this volume, which instead deals with the principles of theoretical chemistry that were known twenty-five years ago, with only a few brief references to mesomerism or other more modern concepts. There is page after page of confusing discussion of the nature of conjugated systems, aromatic compounds, and other molecules for which a single valence-

bond structure does not provide a satisfactory representation.

It is hard to find a justification for the detailed presentation of antiquated structural formulas, with only an occasional statement that the modern views, which provide an explanation of experimental observations that are otherwise hard to interpret, will be discussed in the second volume. The statement in the preface that the material is dealt with essentially in chronological order does not apply here; in fact, the author in this volume discusses a great amount of experimental work that has been published during the past twenty years, but essentially ignores the theoretical progress during the same period. In Chapter 9, on aromatic compounds, there are 123 references to the literature before 1935, and 66 references to the more recent literature—the latter, however, being restricted to experimental papers.

This book is described on the jacket as a suitable text for all students who have taken introductory courses in organic and inorganic chemistry and who know the basic principles of physical chemistry. After comparing the book with "Advanced Organic Chemistry" by G. W. Wheland, in which there is presented a clear, straightforward, and up-to-date discussion of the same field, I am required to say that I would not recommend Hückel's book to any student. On the other hand, a reader who is especially interested in the early history of theoretical organic chemistry might find the book to be of value to him.

LINUS PAULING

GEOLOGY IN ENGINEERING, by John R. Schultz and Arthur B. Cleaves. 592 pages, illustrations, 14 × 22 cm. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd.; 1955. Price, $8.75.

It is important for the civil engineer to know the structure of earth on which he intends to erect a building, a bridge, or through which he intends to dig a tunnel. The significance of adequate surveys of subsurface conditions is quite generally recognized now, but it wasn't always so. Many a contractor, hoping to save some money, omitted test borings, only to find to his grief later that he was building on an old dump or some other rapidly settling fill. Nowadays, on large civil engineering projects such as earth dams, masonry dams or air fields, the importance of geology is so well appreciated that geologists are employed to predict the subsurface conditions so that the design of the particular unit can proceed accordingly. Not only does geology aid engineering as just illustrated, but engineering, in taking test borings or digging tunnels through rock or clay or mud, provides geology with much valuable information. *Geology in Engineering* discusses the various phases of geology that are useful to civil engineering. It is a very broad field, and where the authors have been unable to cover a subdivision, they have supplied abundant references for further detailed study.

Geology in Engineering, written by J. R. Schultz, Chief of the Geology Branch, Waterways Experiment Station, and A. B. Cleaves, Professor of Geology at Washington University, presents in a very factual way the aspects of geology that are pertinent to the broad field of civil engineering. Following an introduction describing the relationship of geology to civil engineering, the minerals and rocks of engineering use are described. Geologic structure, subsurface waters, erosion and the weathering of rocks to form soils are simply explained. An interesting chapter on the formation of the deserts and the various land forms prevalent thereon is presented. The formation of shore lines and beaches, and glaciers and the effect of glaciers are discussed. Such other geologic phenomena as frost action, landslides, volcanoes and earthquakes are explained. In the remaining third of the book, the authors discuss the engineering use of geological knowledge in the construction of such structures as dams, reservoirs, tunnels, highways and airfields. In this part, the usefulness of historical geology, aerial photography and subsurface explorations in predicting surface and subsurface soil conditions is emphasized. A chapter on soil mechanics presents the basic concept of this newest of civil engineering branches.

One who is interested in geology but has had only a smattering of it will find *Geology in Engineering* quite informative. For the well-grounded geologists, the book would

disclose very little. However, for the civil engineer, the book will prove very valuable. It is simply written, easy to understand and very ably shows the connection between geology and civil engineering and how important a sound geological background is for the successful design of such structures as dams, tunnels and airfields.

E. W. HAMMER

NOMOGRAPHY AND EMPIRICAL EQUATIONS, by Dale S. Davis. 236 pages, diagrams, 16 × 24 cm. New York, Reinhold Publishing Corp., 1955. Price, $6.75.

The recent advent of high-speed computing devices and of refined statistical tools in the scientific design of experiments and correlation analysis has not diminished the use of empirical equations which continue to enjoy popularity both with social scientists and some engineers. This astounding phenomenon is readily explained by the fact that empirical curve fittings are more often than not used to develop special charts or nomographs, although purely graphical methods are available and equally accurate. Thus, this text presents a curious mixture of the incongruously empirical with the efficiently essential.

The first part delves deeply into the use of empirical equations for the correlation of experimental data. At the outset, the author rejects the method of least squares as "most laborious" and obtains his equation parameters by using the methods of selected points or of averages. Nevertheless, the least squares computational scheme shown would hardly be considered in a good statistics course and the argument thus loses its strength. The author then proceeds to discuss various forms of transformations to linear relations, $y = ax^b + c$, $y = ab^x$, and $y = a + bx + cx^2$ which are illustrated at hand of numerous examples and drawings. The calculations are carried out step-by-step and the charts are plotted with meticulous care. Some special methods are shown for equations involving trigonometric and hyperbolic functions, but the tenor is strictly empirical, without much recourse to physical laws or relationships. For example, on page 53, we note that the fitting $C = 0.1755 - 1.736 \log Re - (Re^{1.38} + 9)^{-1} + [\log Re (\log Re - 0.602)/(Re + 5.6) - \log^2 Re/(2660 - Re)$ contains more parameters than the table of data which it is purported to fit! Yet the fitting produced "deviations nearly as low as those" obtained by the author in an essentially four-parametric fitting.

"Bumped" data are straightened out by application of a reciprocal hyperbolic cosine term, yet we note that an elaborate table of "cosh n $(X - x)$" is in reality a table of cosh y, for $y = 0(0.01)7.29$, despite the impressive heading. The constants in the Gompertz equation $\log y = \log a + c^x \log b$ are determined for equally spaced values of x by a grouping process; strangely, the author finds it necessary to derive here the formula for the sum of a geometric progression, without even mentioning it as such, yet he does not hesitate to use partial differentiations at other times. The treatment of sigmoid curves introduces a tabulated fitting function $\phi = \log [20\ y/\log (100 - y)]$ which is similar to the well-known logit method of Joseph Berkson but the treatment given it here lacks the sophistication in the latter's approach. No mention is made of Finney's probit method or of other equally important forms of treatment. At the close of this chapter is a summary of frequently used empirical formulas but the listing is not supplemented by graphs as Geffner and Worthing did in their "Treatment of Experimental Data." The last chapter of this first part deals with the problem of three-variable correlation for functional relations of the type $\phi(z) = f(x) + g(x)h(y)$. The treatment by various methods involves essentially cross-sections or cross-plots of the surfaces generated by these equations.

The second part of the book outlines methods for the construction of nomographs which are so useful to the busy plant engineer, especially in frequently repeated calculations. Beginning with addition charts of the form $f(x) = g(y) + h(z)$, the author directs our attention to the numerous requirements that must be made of a good nomograph. Also illustrated is a variation of this form, $1/f(x) = 1/g(y) + 1/h(z)$, and many helpful, practical hints are included to assure proper gradation and direction of scales. The following chapters deal with multiplication charts of the form $f(x) = g(y)/h(z)$ and with recurrent vari-

able charts of the form $f(x) = g(x)\ h(y) + \phi(x)$ or $f(x) = g(y)/h(x) \backsim \phi(u)$. Special chapters treat line coordinate charts and graphical anamorphosis which replaces the empirical curve fitting procedures by graphical methods and thus bypasses debatable analytical fittings. The example given is well detailed and gives the reader an idea of the importance of the purely graphical approach.

Apparently, curve fitting is here to stay, despite the valiant efforts of mathematically inclined engineers and physicists. The latter especially, take little comfort in dimensionally absurd fitting methods but there is little doubt that a large class of more pragmatically inclined empiricists will find much to their liking in this volume. In addition to scores of detailed examples, worked out painstakingly by the author, there are hundreds of interesting exercises running the whole gamut of engineering. A sample page (99) cites problems arising in telephone traffic, the performance of centrifugal refrigeration machines, the drafts needed for gas-fired furnaces, the freeze resistance of Neoprene, the partial vapor pressure of water over aqueous solutions of glycerol, the specific gravity-temperature relationship for rosin size milk, and solids content of alum solutions. All problems are documented by reference to original publications while each chapter is supplemented by an exhaustive list of book references as well. In the eyes of this reviewer, these merits outweigh the somewhat unsophisticated approach inherent in all purely empirical curve fitting procedures, thus giving this publication status both as reference and as class room text.

CARL HAMMER

ELECTRICITY AND MAGNETISM, by Ralph P. Winch. 755 pages, diagrams, 16 × 24 cm. New York, Prentice-Hall, Inc., 1955. Price, $7.75.

This is essentially a college textbook covered in a Junior course by the author at Williams College. It contains elementary concepts on vector analysis, including scalar product, gradient and vector product. The mks. system is used throughout. Chapters cover direct current circuit analysis, magnetic flux and induced emf.'s, the capacitor and inductor as circuit elements, along with a detailed discussion of the time-vector diagram for alternating current circuits, and followed by complex notation.

The second part of the book is concerned with the electrostatic field, electric potential and the properties of dielectrics. Forces on moving charges and current-carrying conductors are followed by a general discussion of the magnetic field and induced emf.'s. Magnetic properties of materials and the circuit application to single phase transformers conclude the author's contribution.

Chapter XIX by D. A. Parti gives a very brief introduction to oscillating circuits and Maxwell's theory.

While the exposition is very readable and certain physical concepts are well brought out, very few new aspects of the subject are introduced. The subject still offers a new approach in the form of electromechanics, where energy transfer relations are interconnected with the electromagnetic and electrostatic fields and where various forms of electromechanical and electrostatic couplings are introduced. It is questionable whether a text of this nature offers any particular advantage over well established texts now in existence.

RUPEN EKSERGIAN

INDUSTRIAL DETERGENCY, edited by William W. Niven, Jr. 340 pages, illustrations, 16 × 24 cm. New York, Reinhold Publishing Corp., 1955. Price, $8.75.

This book, which is a collection of papers by authorities in the various fields where detergency is important, is clearly designed for the engineer with cleaning problems. In the introductory chapter the editor discusses the "practical fundamentals" of the cleaning process as distinct from the theories of the soil removal as a function of surface and interfacial energies. For practical applications, the former approach is probably to be recommended. Soils are classified broadly on the basis of the methods by which they are removed. He then shows how the detergency process must function for effective removal of soil. The material presented in this introductory chapter is not new, but is well organized.

The balance of the book is devoted to discussions of specialized applications of these practical fundamentals of detergency. There are chapters on the peculiar prob-

lems and requirements of the laundry and dry-cleaning industry. The methods, materials and equipment are gone into in some detail. Methods are given for evaluating the results of the cleaning process.

The chapters on cleaning in the food, beverage, and dairy industries point out the considerable progress made in meeting the sanitary requirements in these essential industries. These specialized requirements demanded tailor made detergents and methods. These developments are described.

A chapter on dishwashing presents this ubiquitous drudgery in an encouraging light. Numerous cleaning mixtures are given and evaluated. The many types of equipments are shown and described and evaluated. This is followed by a discussion of the problem of metal cleaning, and general industrial cleaning.

This is a good book and is certainly to be recommended for use by those who want to familiarize themselves with the modern cleaning materials and techniques.

S. N. MUCHNICK

ISOTOPE GEOLOGY, by Kalervo Rankama. 535 pages, illustrations, 18 × 26 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $12.00.

Isotope Geology is the first book to be written on the study of "geological phenomena by means of stable and unstable isotopes of elements and of changes in their abundance." The purpose of the book is "to serve as an introduction to the physics, chemistry, and natural science of nuclides and to acquaint the geologist with their many possible applications."

The author has succeeded in achieving his aim in an admirable way. It is to be expected that this book will become a standard reference not only because of its uniqueness, but because of its general excellence. The order of presentation of subject matter is ideal for reference purposes. The author expressed the desire to have adequate documentation; he has included a 45-page bibliography! References to the literature are inserted throughout the text but have not detracted from the readability in spite of the author's expressed fears. The name and subject indices are long and thorough. It is obvious that the book was prepared with great care and by one well-informed and capable of an excellent synthesis. The sciences of physics, chemistry, astronomy, geology, geophysics, geochemistry and biology all enter into *Isotope Geology*.

The volume is divided into two main sections: I. Physics and chemistry of nuclides and II. Natural sciences of nuclides. Part I begins with a 100-page survey of basic nuclear physics. Then follow chapters on Geological Applications of Radioactivity, Abundance and Origin of Elements and Nuclides, and General Possibilities of Isotope Fractionation in Nature. Among the applications are such diverse topics as age of rocks, age of ruins, well logging, ore concentration, and age and rate of deposition of ocean deposits.

Part II is a 275-page discussion of 79 elements, six of these being trans-uranium elements. As expected, the sections on hydrogen, helium, carbon, oxygen and lead are much larger than those of the other elements. The discussion for each element generally covers the various isotopes, their distribution in various portions of the earth, their distribution and abundance elsewhere, and applications of the measurement of particular isotopic abundance.

Since this book was printed in England, the mass number will be found as a left superscript instead of right.

Isotope Geology should prove to be a valuable reference work for all scientists interested in the abundance and distribution of nuclides. LEONARD MULDAWER

PATENT LAW IN THE RESEARCH LABORATORY, by John Kenneth Wise. 145 pages, 12 × 18 cm. New York, Reinhold Publishing Corp., 1955. Price, $2.95.

In research laboratories and similar organizations, occasionally discussions arise pertaining to patents and their ownership which are sometimes temporarily resolved internally contrary to the patent law and court rulings thereof. The book reviewed here is one which could materially aid such laboratories in establishing a basis for meaningful discussion and patent policies.

On January 1, 1953, the present patent law went into effect, revising and codifying the patent laws previously done formally in

1874. Whereas the old patent law was commonly misunderstood as granting to the patentee "the exclusive right to make, use, and vend the invention," the present law specifically grants "the right to exclude others from making, using, or selling the invention."

In a highly compressed form, this book dissects the law and demonstrates, by examples, the workings of the U. S. patent system. Subjects touched are of interest to all potential patentees. These include: what is patentable; patent rights; employer-employee relationships; applications; transfer and assignment of rights; infringements; and record keeping. Especially stressed is the importance of documentation in a form which would be aceptable to a court hearing patent cases and the fact that an individual other than the inventor should himself personally observe, and if possible, carry out, all the steps leading to the invention.

Research personnel and administrators should find time to read this book if they are at all interested in inventions and patents.

S. CHARP

PRINCIPLES OF EMULSION TECHNOLOGY, by Paul Becher. 149 pages, illustrations, 12 × 18 cm. New York, Reinhold Publishing Corp., 1955. Price, $2.95.

This book is one of the Reinhold Pilot books, and its classification in this manner will immediately tell the interested party that it is a small comprehensive source of information. It is simply written, easily understood and well illustrated.

The text consists of eight chapters whose titles are indicative of the information they contain. Namely: (1) Dispersions and Emulsions; (2) Surface Activity; (3) Theory of Emulsions; (4) The Chemistry of Emulsifying Agents; (5) Emulsification Equipment; (6) The Testing of Emulsion Properties; (7) Emulsion Formulation; and (8) Demulsification. It is concluded with General References, the oldest of which is 1941.

This text—and others like it—is to be recommended for those persons who are interested in a new field and would like a short, rather complete, simply worded treatise.

PHYLLIS A. PARKIN

MOLECULAR VIBRATIONS, by E. Bright Wilson, Jr., J. C. Decius and Paul C. Cross. 388 pages, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $8.50.

It is perhaps easiest to describe the scope of this book by saying what it is not, rather than what it is. Its aim is not to review the rapidly developing techniques for the experimental study of infrared and raman spectra. It does not try to summarize, review, or systematize, the vast amount of this type of data now available. Nor does it consider the relationship between molecular vibration, rotation and the calculation of thermodynamic properties of molecules. Finally, molecular vibrations in the liquid or solid state and the corresponding spectra are not treated.

The aim is to present the modern theory of the vibrations of isolated, non-interacting (that is, gaseous) molecules as it is used to predict spectra and conversely, as it enables information on molecular architecture to be inferred from observed spectra. To achieve this aim, the authors first present the simpler methods, bypassing much of the detail in favor of simplicity. In later chapters the more complex procedures involving group theory are treated. The arrangement of the book is flexible so that the reader may, if he so desires, skip some of the more specialized material such as that on isotope effects.

The reader is assumed to have a basic knowledge of quantum mechanics. But the emphasis is not on the quantum mechanics of molecular vibrations, but on the methods of treating moleculars with many modes of vibration. This, of course, requires the use of advanced mathematics, in particular matrix algebra and group theory. These subjects are introduced and explained where needed, partly in the text and in more detail in the appendices. Several other topics of less direct bearing are given in the appendices. The last chapter on the separation of rotation and vibration might well have been called an appendix, since this material was bypassed in the earlier parts of the book.

The body of the book is closed with a sample vibrational analysis for the benzene molecule.

E. R. STEPHENS

DYNAMICS OF MACHINERY, by A. R. Holowenko. 464 pages, diagrams, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1955. Price, $7.50.

Written by an Associate Professor of Mechanical Engineering at Purdue University, A. R. Holowenko, *Dynamics of Machinery* is confined to kinematics and force analysis of the fundamental motions of machines. Profuse with illustrations and examples, the book is factual, fairly elementary and not very broad in scope. The treatment is sound and obviously aimed at the second or third year college level.

The determination of velocities and accelerations for the moving links of various machines—but principally for the slider-crank mechanism—by analytical and graphical methods occupies about half the volume. Static force and dynamic force analyses of the same machines form another quarter of the book; and the remaining quarter is concerned with flywheel analyses, the balancing of rotating and reciprocating masses in one or more planes, shaft vibrations and a short chapter on gyroscopes.

While the book is restricted to the analysis of a selected few machines, it is not really so limited in scope if it be recognized that the basic principles of kinematics and dynamics described are applicable to all machines. This is the main value of the book —an orderly, sound presentation of analytical and graphical methods for determining the forces in the basic, moving parts of machinery.

E. W. HAMMER

THE ELEMENTS OF CHROMATOGRAPHY, by T. I. Williams. 90 pages, illustrations, color plates, 13 × 19 cm. New York, The Philosophical Library, no date. Price, $3.75.

To those who are not acquainted with the techniques of chromatographic analysis, this book offers an interesting introduction to the materials, equipment, and methods of this phase of analytical chemistry.

The author traces the development of the methods of chromatography from their first use in the dye stuff industry of Germany to the present, and thus fortified with the historical background the reader is taken into the discussion of adsorption or column chromatography. Partition chromatography or paper chromatography is discussed, followed by a brief chapter on ion exchange chromatography.

No specific schemes of analysis are described. The discussions serve mainly to describe the various types of apparatus which have been used and the necessary qualifications of papers, column packings, and solvents. The reader is left to select elsewhere an exact analytical scheme.

Theoretical development of chromatography is kept to a minimum throughout. For the reader interested in further work in the field, a bibliography of more advanced works is supplied.

This book could aid interested persons in selecting the type of apparatus and technique best suited to their specific laboratory needs.

R. H. HOLLINGER

BOOK NOTES

TRAVELS OF WILLIAM BARTRAM, edited by Mark Van Doren. Unabridged edition with all 13 illustrations from the original edition. 414 pages, 14 × 20 cm. New York, Dover Publications, Inc., 1955. Price: $1.95 (paper); $3.95 (cloth).

Not only nature lovers and travel enthusiasts, but historians and anthropologists will welcome this reissue of one of the most accurate records of Southern wildlife and Indian customs. This is the first popular-priced edition of this 154-year old classic, which has been used as source material for some of Coleridge's best poems and as an inspiration to Wordsworth. Bartram's vivid descriptions of rivers, swamps and lakes, and his scientific observations of the habits of birds, snakes, fish and Indian tribes make this a fascinating account of life in the South, back in the 1770's.

THEORY OF ALTERNATING-CURRENT MACHINERY, by Alexander S. Langsdorf. Second edition, 666 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $8.50.

This new edition of a standard text will be welcomed, for it brings up-to-date the useful material found in the first edition, and discards much material that has become outmoded since the advent of electronics. As an example of the revision, circuit theory has been omitted, since it is now taught in more elementary courses. Also, a chapter on power rectifiers and inverters has been added. In line with modern practice, the rationalized mks system is used, and the old "vector" and "vector diagram" have been changed to "phasor" and "phasor diagram." There are more problems in the new edition —both to illustrate the text, and as problems at the end of the chapter, for student solution.

ELEMENTS OF ELECTRONICS, by Henry V. Hickey and William M. Villines. 487 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $6.50.

Aimed at technicians, this new book stresses actual practice. It is suitable for a training course for radio and electronics technicians interested in learning the fundamentals of electronics. It is intended for beginners. Fifty chapters cover details of such electrical and electronic devices as ammeters, vacuum-tube voltmeters, parallel and series circuits, power transformers, transmitters, batteries, amplifiers receivers and transistors. Each chapter has many simplified explanatory diagrams. Mathematics is kept to a bare minimum.

MANAGEMENT AND LEADERSHIP, by Carl F. Braun. Revised edition, 289 pages, 16 × 22 cm. Alhambra (Calif.), C. F. Braun & Co., 1954. Price, $3.25.

Published for the employees of C. F. Braun & Co., this book is an attempt to bring management's role to the attention of those employees who are classed as "leaders" themselves—executives, project leaders, foremen, etc. In simple terms, the book covers such subjects as "What is Industry? and Why?"; "Leadership"; "People Before Plant"; "Discipline"; "What Price Plant"; "Employment-Manners"; and "Leaders Must Lead." A section "Some Good Books in the Social Sciences" lists 14 books, with comments on each to guide the reader in his selection. (One of the 14 is Franklin's "Autobiography.") The style of the book is "folksy" and the text is sprinkled with Biblical quotations, proverbs, etc. It was written for the "industrial leader" to stimulate a "fuller recognition of his high social responsibility for the development of the people he leads." Judging from its style and content, the book could also have been written for all employees as an explanation of the role of management.

PUBLICATIONS RECEIVED

GEOLOGY: PRINCIPLES AND PROCESSES, by William H. Emmons, George A. Thiel, Clinton R. Stauffer and Ira S. Allison. Fourth edition, 638 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $6.50.

THE ELEMENTS OF ASTRONOMY, by Edward Arthur Fath. Fifth edition, 369 pages plus 8 charts, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $5.50.

INTRODUCTION TO PHYSICS, by Frank M. Durbin. 780 pages, diagrams, 16 × 24 cm. New York, Prentice-Hall, Inc., 1955. No price.

ASTRONOMY, by Freeman D. Miller. Vocational and Professional Monograph No. 72. 32 pages, 15 × 23 cm. Cambridge (Mass.), Bellman Publishing Company, 1955. Price, $1.00 (paper).

PROCEEDINGS OF THE EASTERN JOINT COMPUTER CONFERENCE. 92 pages, illustrations, 22 × 29 cm. New York, The American Institute of Electrical Engineers, 1955. Price, $3.00 (paper).

SPECIFICATION FOR DRY CELLS AND BATTERIES. Sixth edition, NBS Circular 559, 17 pages, illustrations, 20 × 26 cm. Washington, U. S. Department of Commerce, 1955. Price, $0.25 (paper).

THE BIRTH AND THE DEVELOPMENT OF THE GEOLOGICAL SCIENCES, by Frank Dawson Adams. Unabridged republication of the first edition (1938), 506 pages, illustrations, 14 × 21 cm. New York, Dover Publications, Inc., 1955. Price: $1.95 (paper); $3.95 (cloth).

THE CONTINUUM AND OTHER TYPES OF SERIAL ORDER, by Edward V. Huntington, with an introduction to Cantor's Transfinite Numbers. Unabridged and unaltered republication of the second edition (1917), 82 pages, 14 × 21 cm. New York, Dover Publications, Inc., 1955. Price: $1.00 (paper); $2.75 (cloth).

ALMOST PERIODIC FUNCTIONS, by A. S. Besicovitch. Reissue of the first edition, 180 pages, 14 × 21 cm. New York, Dover Publications, Inc., 1955. Price: $1.75 (paper); $3.50 (cloth).

ANCIENT EDUCATION, by William A. Smith. 309 pages, 14 × 21 cm. New York, Philosophical Library, 1955. Price, $3.75.

TO MEMBERS AND THOSE WHO KNOW THE FRANKLIN INSTITUTE

All of us associated with The Franklin Institute are gratified by the support given by its benefactors in the past. Without their generosity our privately endowed Institute would have been unable to serve industry, the professions, and the public as it has and should.

There is still a continuing and pressing need of contributions and bequests —both for general and specific endowment, and of income to be judiciously used. Your response will be most earnestly appreciated.

Checks should be made payable to The Franklin Institute, and sent to The Franklin Institute, Benjamin Franklin Parkway at 20th Street, Philadelphia 3, Pennsylvania.

Where property is transferred, title should be in the name of The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.

We shall be glad to supply any additional information regarding gifts and memorials. Please write to the above address, attention of the Endowment Department.

CURRENT TOPICS

Electronic Brain for Analyzing Human Brain.—A new electronic computer for analyzing the rapid and complex electrical activity of the brain is now in preliminary tests at the Massachusetts Institute of Technology and the Massachusetts General Hospital. It displays in a new and rather different form the information in these tiny electrical impulses that are related to the nervous system's operating and controlling mechanism. By automatically comparing brain waves in one short time period with those which preceded them, the computer shows a time sequence of brain wave activity.

This computer, say its designers, makes it easier to answer such questions as: "How stable a phenomenon are brain waves? Are there wave patterns which repeat periodically? If a range of normal stability for brain waves can be defined, can we then determine variations from this norm in children; in older people; in those with mental disease?"

These are some of the questions and speculations of scientists at M.I.T. and the Massachusetts General Hospital in the excitement of exploring this new tool. It is still too early, they insist, to promise that these or other questions will be answered.

But Dr. Norbert Wiener, Professor of Mathematics at M.I.T., who is largely responsible for the mathematical developments which are the basis of this method, believes "it is inconceivable that this method will not prove of major significance."

In an invited lecture at the University of Southampton, England, Dr. Wiener described the use of this new equipment to show the rhythms of the well-known waves which have long been familiar to medical research. The new form of presentation, Dr. Wiener said, now permits us to describe these as "an accurate clock in the brain of man—a clock of good consistency, beating about 10 times per second, and keeping phase with itself for perhaps hundreds of seconds.

"Clocking is both a useful and recognized phenomenon in many mechanical control machines," Dr. Wiener continued, "and it seems likely to be equally essential in the control machine of the brain. Here we think it may have something to do with the human's intelligence and organized functioning."

The clock-like signals are found combined with a great number of tiny random pulses. The contribution of the new machine at M.I.T. is to sort automatically this random activity in order to get at such consistent signals as these Dr. Wiener describes.

In some individuals, Dr. Wiener said, these minute but precise electrical signals following one after another "stand out with the utmost clarity and persistence, continuing at about a constant level for what we know to be as much as fifteen seconds." In other cases, this signal is not so clear or persistent; for the present there seems no way to know the basis of these differences.

The preliminary results which Dr. Wiener has described came from equipment developed in the Research Laboratory of Electronics at M.I.T. in conjunction with a research group at the Massachusetts General Hospital. Dr. John S. Barlow of the Massachusetts General Hospital and Mr. Robert

M. Brown of M.I.T.'s Research Laboratory of Electronics began work in 1952 on this analog correlator, a type of very specialized computing machine. The machine has been in use for several months in tests conducted under the direction of Dr. Mary A. B. Brazier, Neurophysiologist to the Neurological Service at the Massachusetts General Hospital, and Dr. Walter A. Rosenblith, Associate Professor of Communications Biophysics at M.I.T., both important contributors to the machine's development.

Dr. Wiener, whose early work in mathematical analysis and correlation laid the foundation for the developments now being reported, is also participating actively in the current work.

The electrical activity of the brain is extraordinarily complex. Systematic analysis of this activity has been heretofore impossible except on a relatively very limited scale.

"All nervous activity is accompanied by electrical signals," says Dr. Brazier. "Since the first discovery of these brain waves," she says, "scientists have focussed their attention on efforts to sort out various components of this pattern and to understand the relationships between them.

"As a result, for many years we have known that brain waves contain elements important in diagnosing disease and in learning more of the fundamental processes of human thought and action. But our tools have been inadequate to answer many of the most important questions."

"Our present analog correlator," Professor Rosenblith says, "takes brain waves as recorded on tape, processes them, and, in an operation almost entirely automatic, prints a graph that indicates the continuity of the patterns over the time intervals we may choose.

"The development of this specialized equipment," Dr. Rosenblith points out, "is not only a tribute to Dr. Wiener's ideas; it is also a very practical illustration of the way in which medicine, the biological sciences, mathematics, and electrical engineering combine forces to attack age-old problems."

Members of this M.I.T.-Massachusetts General Hospital group emphasize that the work is just beginning, only a few records have thus far been analyzed, and no final conclusions are justified.

But, they say in commenting on Dr. Wiener's report, "it seems reasonably clear from the regularities and consistent patterns that we have found in both human and animal records that here is indeed a promising technique for analyzing the brain's electrical activity. Many variables will have to be investigated, many controlled experiments must be run, but the fact that we now have a more convenient way of observing and measuring the stability of the brain's electrical activity is a big step forward."

"Many competent electro-physiologists," says Dr. Rosenblith, "have become convinced during this last decade that they will need all the help they can get from electronic computing devices. In this view computers such as that developed at M.I.T. will open up new frontiers both in the processing of biological data and in the formulation of theoretical models."

Food from the Ocean.—A Worcester Polytechnic Institute junior has a plan to tap the ocean's limitless food supply. His idea won him $25 in the college's annual Wilfred L. Peel contest for developing an engineering-economic idea. It may be his entrance into a revolutionary field often dreamed by scientists, but never realized, and a prize of untold riches.

The plan of Robert L. Diamond of

Worcester to process a food supply from the microscopic animal and plant life of the sea is based on a technique already used in a number of industrial applications. His was developed in collaboration with his brother, Edward Diamond of Hartford, Conn., who was graduated from WPI in 1943.

Science has long pointed to the ocean's teeming microscopic life, called plankton, as the answer to the world's food problem. The difficulty is in "catching" microscopic "fish."

The most plentiful variety of these organisms is unfilterable by any known commercial process. The Diamond proposal is not to make the mesh of any filtering screen smaller, but to make the diatoms bigger . . . by supersonic vibrations.

The plan is to pump sea water through a cylindrical crystal at the precise frequency necessary to cause the tiny particles to collide with one another, to bunch up and to stick together.

Deep sea explorers report that plankton is as thick as soup at the lower levels of the ocean. Diamond in winning the Worcester Tech prize outlined a plan for segregating and processing at a cost far below that of the cheapest protein source now available for animal feed. He would have oil as a byproduct and the possibility of use as a basic food for man.

"Perfect" Iron.—Pure and perfect slivers of iron, having breaking strengths approaching a million psi.—far greater than any other known metal—have been produced on an unprecedented scale by scientists at the Westinghouse Research Laboratories. The slivers of iron, or "whiskers" as they are called, are each a pure iron crystal so perfect that no defects can be detected in its structure. The crystals are as much as 2 in. long and a thousandth of an inch thick. Previous attempts to produce these "whiskers" have given crystals which could be observed only with the aid of a microscope.

"Perfect iron is another forward step in our attempt to gain a broader understanding of the fundamental properties of metals," said Dr. J. A. Hutcheson, Vice President in charge of research. "Because of their strength, hardness, ductility and other useful properties, metals have always been the backbone of civilization. But it is interesting to note that all these desirable properties of metals, as we know and use them today, are actually determined not by the metal itself but by the impurities and imperfections it may contain."

Very little is known about metals that are completely free of impurities and imperfections simply because they are never found in nature and, until recently, could not be prepared in the laboratory.

Theoretically, however, it is known that such metals should exhibit fantastic properties which could make them extremely valuable to man. For example, pure iron has an ultimate tensile strength of more than a million psi. This is at least 10 times the strength of ordinary iron which has been hard drawn into wire and at least three times the strength of the kind of steel used in making piano wire.

"Pure and perfect iron will not emerge tomorrow as a brand new construction material," Dr. Hutcheson added, "but at last it has been prepared on a scale large enough that we can make a realistic study of it and begin to find ways to utilize the unusual properties it possesses."

Preparation of the perfect iron and testing of its mechanical properties was done by Drs. A. W. Cochardt, H. W. Wiedersich, and R. L. Eisner of the

metallurgy department of the Westinghouse Research Laboratories. The iron is the result of the perfection of a new "whisker growing" technique which was originated in the Laboratories about two years ago by Dr. John C. Kelly, physical chemist in the magnetics and solid state physics department.

The perfect iron "whiskers" were made in this manner:

Highly purified iron chloride, a common "salt" of iron, is heated in an atmosphere of hydrogen gas inside a special furnace at a temperature of about 1100° F. Through rigid control of the temperature and flow of hydrogen, the chlorine atoms in the iron chloride are allowed to unite chemically with the hydrogen at a certain precise rate. This leaves unattached atoms of iron, which "migrate" slowly toward each other and deposit one upon another in perfect arrangement. Thus, billions of iron atoms "grow" without any observable defects into a single perfect crystal of pure iron, exactly square in cross section, and often attaining a length of 2 in.

"Brainstorming" Sessions at Research Labs.—"Brainstorming" has begun at the Corps of Engineers Research & Development Laboratories, Fort Belvoir, Virginia. Initial creative sessions demonstrating conference techniques for the generation of ideas and the solution of technical problems were conducted there recently by Pfc. Walter C. Mansfield of the Chemical Corps' Materiel Command Headquarters, Baltimore, Maryland.

A former instructor in General Electric's creative engineering program, Mansfield led four sample "brainstorm" sessions during his two-day stay at the Laboratories. Two of the sessions dealt with special problems in petroleum distribution, and the remainder with mine field and bridge problems.

In general, the sessions consisted of a presentation of the problems to a cross section of the Laboratories' engineering personnel, consisting of both those engaged in and those not engaged in the work under discussion and recording of their on-the-spot solutions.

Although designed principally to serve as an introduction to the method of "brainstorming" or "imagineering" which has been in use in industry for some time, the sessions have already resulted in many good "leads" for project engineers, according to Mr. Kenneth L. Treiber, ERDL Liaison Officer, who is coordinating ERDL's creative engineering program.

Deeminizer Takes Minerals Out of Tap Water.—Ordinary tap water can now be transformed into mineral-free water by a new, economical method —good news for pharmaceutical, chemical, hospital, and photographic laboratories, and other activities. A unit called the Deeminizer does the job at the rate of 5 gallons per hour, producing water with an ionic content of less than 1 part per million.

The Deeminizer unit consists of a transparent, practically unbreakable tower or reservoir made of Tenite acetate plastic, which is assembled to a base containing a quality-check meter. An ion-exchange resin filter is placed inside the tower and a gallon jug or similar container of ordinary drinking water upended in the tower top. The water flows by gravity through the resin, filtering into the lower part of the tower ready for instant use. The meter in the base provides a constant check on ionic content. Purified water may be drawn off by releasing the spring clamp on outlet tubing running from the base.

Compact and lightweight, the Deem-

inizer unit is readily portable and occupies only 6 × 8 in. of bench space. The meter plugs into standard electrical outlets. No plumbing connections at all are needed. The Deeminizer is produced by Crystal Research Laboratories, Hartford, Conn.

Automatic Check Endorser.—Introduction of a new flexible high speed automatic check endorser to be used in conjunction with Burroughs Micro-Twin microfilm recorder and reader, or the Twin without the reader, has been announced by Burroughs Corporation, Detroit, Mich.

Featuring an interchangeable printing head that can be installed or removed without opening the microfilm machine, the new endorser will accurately endorse checks at the same time and at the same speed with which they are microfilmed. It can be used to endorse, cancel or imprint other material on documents.

Use of the endorser assures the user that each check receives a complete, distinct and individual endorsement in the proper position. In addition, the day, month and numerical coding number necessary can be changed from the operator's position without removing the endorser head, without making any internal adjustments or touching any inked parts.

Equipped with an easily filled ink reservoir, the endorser has a cylindrical ink pad. To re-ink, the operator simply presses a remote control lever that releases ink to the roll only when the head is in printing position and in motion.

The endorser printing head is quickly and easily changed. Extra printing heads may be purchased if more than one type of endorsement is required. Designed expressly for use on the compact Micro-Twin, the new endorser can be quickly installed on machines now in use. It fits snugly out of the way just above the machine hopper that receives documents after they have been microfilmed.

Water Bath with Infra-Red Heat.—The first precision water bath utilizing infra-red heat has been placed on the market by the Chicago Apparatus Company. The bath is for use in industrial, research, and control laboratories.

The unit maintains a constant temperature within 0.001° C. to eliminate a variable factor in any scientific investigation where temperature is subject to change. It features external circulation and a large working space.

Controls, the infra-red heater and the circulating pump are located in the base of the unit, providing maximum work area in the jar. Operation outside the nominal temperature range may be obtained without placing accessory equipment in the bath. Work area is therefore equivalent to that of much larger tanks with immersed heater and circulators.

A precision thermoregulator, a sensitive electronic controller, infra-red heating with adjustable output and marginal operation for higher temperature ranges, and a powerful centrifugal pump all contribute to the high precision of the bath, the company said.

The external circulator with adjustable flow is provided for maintaining other instruments at constant temperature, or for heat-exchange cooling of the tank water when operating at below-room temperatures. External fittings permit the use of heat-exchange cooling outside the bath.

The nominal operating range without accessory equipment is approximately room temperature to 65° C. The high temperature range may be extended by auxiliary infra-red lamps which may be mounted on the bath

support rods. All controls and fittings are rated for operation between 10 and 100 degrees Centigrade.

It is pointed out that the unit eliminates shock hazards. Since there is no stirrer or immersion heater in the bath, there is no possibility of contact with the power circuits. Thermoregulator leads are completely isolated and are a ground potential. Power leads in the base of the unit are protected by waterproof plastic tubing, and a grounding terminal is provided.

The bath is being offered in two sizes: one with a container 12 in. in diameter and 12 in. in height, with over-all dimensions of 15¼ by 16¼ by 18¾ in. high; and the other with a container 12 in. in diameter by 18 in. in height, with over-all dimensions of 15¼ by 16¼ by 24¾ in. high.

Ultrasonics in Pickling and Descaling, and Electroplating.—Two new industrial processes using ultrasonic vibrations in liquids have been announced by The General Ultrasonics Company, Hartford, Conn.

The *Sonistrip* * *Process* greatly accelerates and improves the efficiency of pickling and descaling of metals in acids and caustics. Welded stainless steel Sonicells,* impervious to most corrosive fluids, are immersed in acid or caustic solutions and radiate ultrasonic vibrations at 19,800 cps. This greatly accelerates the pickling and cleanup effects of the solutions due to ultrasonic "cavitation." Rust, oxide and scale removal are accomplished in 10 to 90 sec. compared with 10 min. to 1 hr. by previous methods. Interior surfaces and deep crevices are pickled or descaled in the same short time as outer surfaces.

The *Soniplate* * *Process* accelerates and improves electroplating and electroless plating by introducing ultrasonic vibrations into the plating bath. If required by the characteristics of the solution, the stainless steel Sonicells * can be further protected by resin coating. The vibrations and accompanying "cavitation" cause rapid replacement of the exhausted or saturated liquid layers ordinarily surrounding anode and cathode, and increases of 2 to 100 times in plating current density without "burning" have been noted. Edge build up is eliminated or minimized. Throwing power is increased. Anode polarization is eliminated. Grease, rust or dirt which may have remained on the work due to imperfect precleaning are simultaneously removed by ultrasonic action, and the result is better plating and fewer rejects.

Ultrasonic degreasing in trichlorethylene has been known for some time, but the key to these new practical pickling, descaling and plating processes developed by The General Ultrasonics Company is the new line of stainless steel, hermetically sealed Sonicells * which can be immersed in corrosive or conductive liquids and are therefore useful for many processes impossible for earlier types of transducers. These Sonicells * are installed one to each square foot of tank side or bottom area and can therefore be arranged as necessary for use in new or existing tanks of any size. For small scale production they are powered by electronic generators. Large arrays of Sonicells * are driven by motor-alternator equipment which can be furnished with any required power output. As an example, a 5 kilowatt motor-alternator furnishes power for a Sonicell * installation in a pickling or plating tank of 10 sq. ft. of side or bottom area. Larger and smaller units are offered to satisfy almost any production requirement.

* Trade Marks of the General Ultrasonics Company.

Double-Duty Roll-About Fan.—Precision Equipment Co., of Chicago, has announced production of a new electric fan, named the Roll-About because it moves easily from one location to another on extra heavy duty rubber wheels. Roll-About's giant 20-in., deep-pitched propeller moves free air at the rate of 3950 cu. ft. per minute. A big, rigidly mounted and cushioned-in-rubber 2-speed motor runs silently with no radio/TV interference. Roll-About is a double-duty performer. Placed anywhere, it circulates cooling breezes throughout the room. Rolled in front of an open window, it efficiently exhausts hot, stale inside air—drawing in fresh air from the outside and cooling up to three rooms. Added to Roll-About's power and versatility, its easy portability multiplies its value to industrial plants, shops, stores, garages, laundries, restaurants, schools, homes and apartments.

New Aircraft Gyro Motor.—A new hysteresis-driven Type GAA aircraft gyro motor introduced by Westinghouse as a basic component for miniaturized hermetic gyros is applicable to position or rate gyros in fire control and automatic guidance systems. The new units display excellent dimensional stability over a wide range of operating conditions. Designed for accuracy throughout their service life, they experience only a negligible shift in center of gravity.

New open-slot construction permits development of greater torque than was possible previously. This increase in torque reserve makes the new design adaptable to applications in which low temperature starting without heaters is desired. Use of a synchronous hysteresis-type motor and the rigorous control of inertia during manufacture combine to insure highly consistent angular momentum. Inertia values are adjusted to provide rated angular momentum within $\pm$ 0.5 per cent.

To meet requirements of floated-type gyroscope construction, dynamic inbalance is limited through tolerance controls to values less than 0.00092 oz.-in. Higher degrees of dynamic balance can be attained through advanced balancing techniques.

Assembled in a controlled environment for stable performance, all motors are run for at least 16 hr. before final test. Maintenance-free service life of 1200 hr. is guaranteed, but field data indicate that longer life can be expected from hermetically sealed units.

The new gyro motors are rated 100,000 gram-cm^2 radians per second at 12,000 rpm. and designed for use with a 10-volt, 3-phase, 400-cycle power supply. Weight is 76.4 ± 1.5 grams; over-all length, including mounting shaft, is 1.290 in.; and wheel diameter is 1.555 in.

Through negotiation, the new gyro motor can be supplied in designs suitable for non-standard conditions of dynamic balance, operational environment, and voltage.

For further information on the new Type GAA gyro motor, write the Westinghouse Electric Corporation, Aircraft Department, Lima, Ohio. All inquiries will be processed in strictest confidence, with respect to the national security and commercial interests.

Engineers Announce New Power Jack.—A self-propelled hydraulic power jack has been developed by the Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Va., and the Kershaw Manufacturing Company of Montgomery, Alabama, to speed-up surfacing of railroad tracks. Propelled by a hydraulic motor with a two-speed transmission, the unit

has a working speed of 3 mph. and can travel at speeds as high as 12 mph. It has rail "dogs" which operate automatically on any size track as the foot is lowered between ties. One man can operate the unit, which is equipped with a special turntable to permit its removal from the track in less than two minutes.

The unit is one of several items under development and test at the Laboratories to accelerate the construction and repair of military railroads. Others are a maintenance car, a track shifter, a ballast tamper, a rail cutter and a hydraulic rail bender.

Largest X-Ray Machine for Cancer.—What is believed to be the most powerful machine in the world yet available for the treatment of cancer—a 15-million volt linear accelerator—has been delivered to St. Bartholomew's Hospital in London, by Mullard Research Laboratories, Salfords, England.

The accelerator produces the 15-million volt X-rays at a very high intensity—roughly 3000 roentgens a minute at a distance of about a yard. Apart from the advantages offered by such high-energy radiation in the treatment of cancer, the machine makes it possible to investigate two new radiotherapy techniques—electron therapy and neutron therapy.

In electron therapy, the electrons themselves are brought out from the machine and used to irradiate the tumor, penetrating the tissues to a depth of three inches.

With neutron therapy, it is thought it may be possible to localize the therapeutic action of the neutrons in definite regions of the body. This result is quite different from those achieved by X-rays.

The linear accelerator lends itself particularly well to research in radiobiology—the action of radiations on living tissues, and the destruction of cells by the passage of ionizing radiations. It is, in fact, the first large-scale equipment to be devoted full time to this type of investigation.

A similar machine has been ordered by the Harwell Atomic Energy Research Establishment for research in nuclear physics.

New Shadow-Microscopes.—Cambridge University Cavendish Laboratory, where the atom was first split by Cockcroft and Walton in 1932, has produced the first practicable X-ray shadow microscope. This is an instrument by which the internal structure of biological and metallurgical specimens can be made visible in great detail and in three dimensions.

The microscope, one of the many new scientific instruments and pieces of apparatus seen recently at the Physical Society Exhibition in London, is about to be produced in quantity.

Of the small number that have left the laboratory, two have gone to the United States—one to the National Institute of Health in Washington, the other to the University of Redland in California—while the unit on display at the exhibition is earmarked for Stanford University.

The new microscope produces a point source of X-rays for shadow projection X-ray images and has a magnification of at least 2500 times. The image reproduces the internal detail of the specimen in three dimensions. It is said that the resolution obtained is comparable to that of the best light microscope.

Applications other than in biology and metallurgy include its use as a point source for X-ray crystallography.

Microscope Accessory to Measure Strain in Glass and Plastics.—A microscope accessory to simplify the

measurement of strain in glass and plastics has been introduced by the Bausch & Lomb Optical Co., Rochester, N. Y. Known as an accessory slot compensator, the device is for use by manufacturers of glass and plastic containers, and producers of metal-and-glass products such as vacuum tubes.

The presence of strain in glass and plastics has an important bearing on their structural strength. Many items such as vacuum tubes and wrap-around windshields are made stronger when they are built with a controlled amount of bending strain.

Many types of glass food containers, on the other hand, must be free of strain because they undergo rapid temperature changes that might cause breakage. The accessory slot compensator will speed tests on such products.

The first step in measuring strain is to measure "birefringence" with the accessory slot compensator. Determination charts are then used to obtain readings. Determinations correct to ± 2 per cent without calibration are read directly in millimicrons from a scale engraved on a rotatable drum. No computations or conversion tables are needed and training time is substantially reduced.

The instrument performs with greatest efficiency when used with light having a wavelength of 5890 Å. To achieve this light value, an interference filter is available for use with tungsten illuminators.

Retardations from 0 to 2700 millimicrons can be measured simply with the B & L accessory slot compensator. Scale division values engraved on the side of the instrument provide a permanent record and a means of ready reference.

Analyzer for Hydrogen in Titanium.—For those concerned with hydrogen embrittlement of titanium, National Research Corporation, Newton Highlands, Mass., announces the introduction of the Model 917 Hydrogen Analyzer. Equally suitable for either quality control or research, this analyzer is a laboratory analytical apparatus for the rapid and precise determination of the hydrogen content of titanium, zirconium and similar metals and alloys.

Using approximately 0.25-gram samples in any solid form such as sponge, chips, or drillings, the equipment has a precision of better than ± 5 percent over the range from 5 to 700 parts per million. A complete analysis takes from 3 to 10 minutes.

Simple to operate and maintain, the Model 917 Analyzer can be run by any competent laboratory technician. Installation of the unit and instruction of the operator are included with the purchase.